SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the Federation of Sewage and Industrial Wastes Associations

Special Features

Disinfection with Chlorine—Heukelekian and Smith

Sewage Service Charges—Tatlock

Colorimetric Metals Determination—Butts, Gahler, and

Utilization of Natural Purification Capacity—

Stream Loadings—Imhoff

DECEMBER, 1950—VOL. 22, No. 12

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Please remit immediately upon receipt of the first dues notice from your Member Association Secretary.

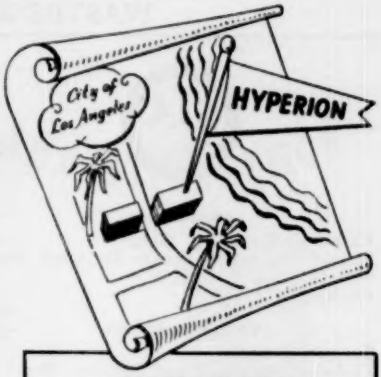
FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

325 Illinois Bldg. Champaign, Ill.

Congratulations

TO THE CITY OF LOS ANGELES
ON THE OPENING OF THE

HYPERION PLANT



We salute the city which sponsored and the men who planned and built the Hyperion Activated Sludge Plant. One of the world's largest, it typifies progressive, modern Sewage Treatment design and construction. We are proud that CHICAGO Sewage Equipment is playing such an important part in its operation, as it is in thousands of other plants all over the world.

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TO THE MEN WHO BUILT
HYPERION

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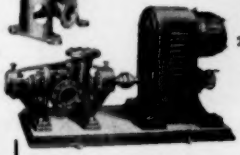

27 Screw-Feller Sludge Pumps

22 Bilge Pumps and Miscellaneous Circulating Pumps

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A monthly Journal devoted to the advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage and industrial wastes, and the design, construction, operation and management of such works.

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HOW TO MEASURE TRADE WASTES ACCURATELY

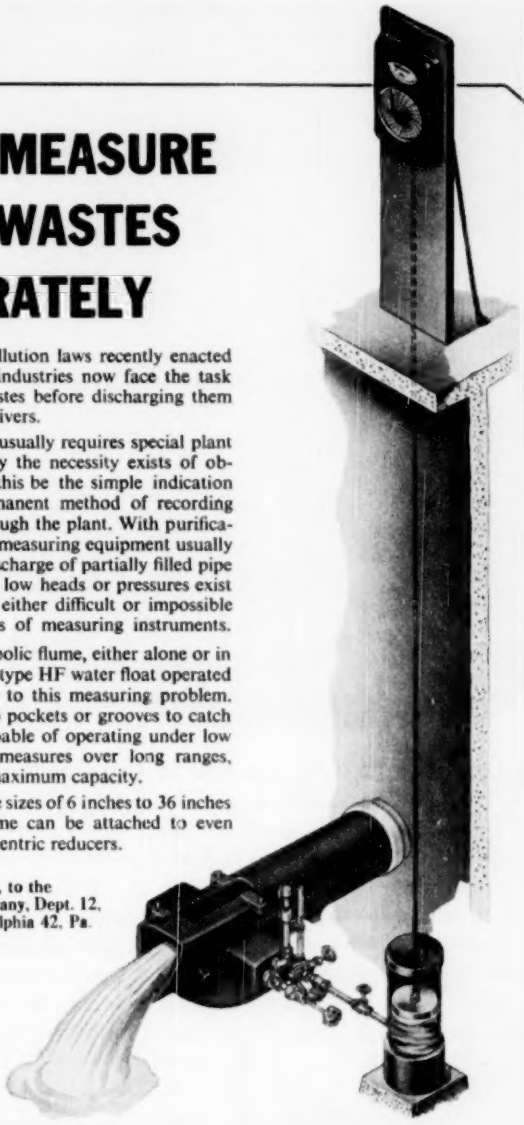
In accordance with anti-pollution laws recently enacted by numerous states, most industries now face the task of purifying their plant wastes before discharging them into adjacent streams and rivers.

This purification process usually requires special plant construction, and invariably the necessity exists of obtaining flow data, whether this be the simple indication of flow rate or a more permanent method of recording and totalizing the flow through the plant. With purification processes of this kind, measuring equipment usually is located at the point of discharge of partially filled pipe or in open channels, where low heads or pressures exist and where measurement is either difficult or impossible when using standard forms of measuring instruments.

The Simplex type S Parabolic flume, either alone or in conjunction with a Simplex type HF water float operated meter, is the ready answer to this measuring problem. Compact in design, with no pockets or grooves to catch sediment or solids, and capable of operating under low flow conditions, the unit measures over long ranges, from maximum to 5% of maximum capacity.

Available in standard pipe sizes of 6 inches to 36 inches diameter inclusive, the flume can be attached to even larger sizes by means of eccentric reducers.

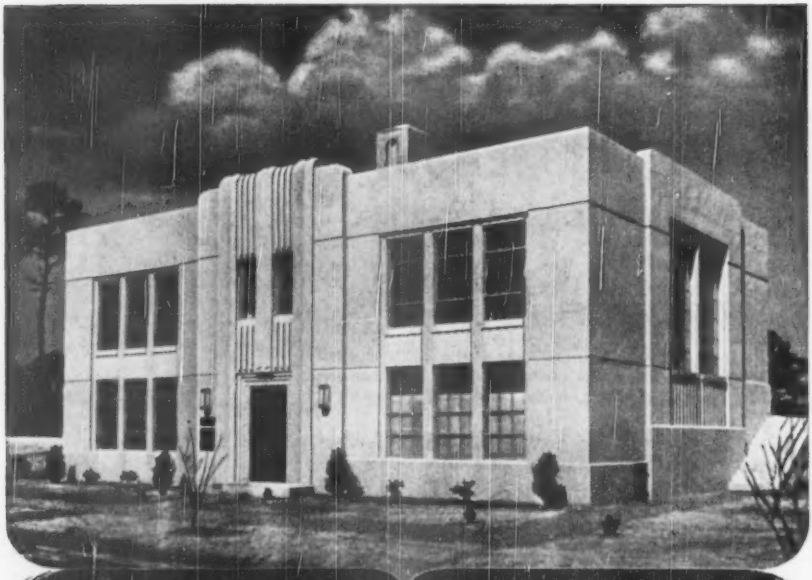
Write for Bulletin 210, to the Simplex Valve & Meter Company, Dept. 12, 6719 Upland Street, Philadelphia 42, Pa.



IT'S SIMPLEX IT'S ACCURATE

SIMPLEX

VALVE AND METER COMPANY



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Write for *"Sewage Treatment Works,"* a free 24-page booklet describing treatment methods, the need for such plants and how they can be financed; also free folder *"S-101,"* picturing sewage and waterworks plants. Distributed only in the United States and Canada.

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Illustration above shows the architectural concrete service building at Virginia Beach, Virginia. Wiley & Wilson were the consulting engineers.

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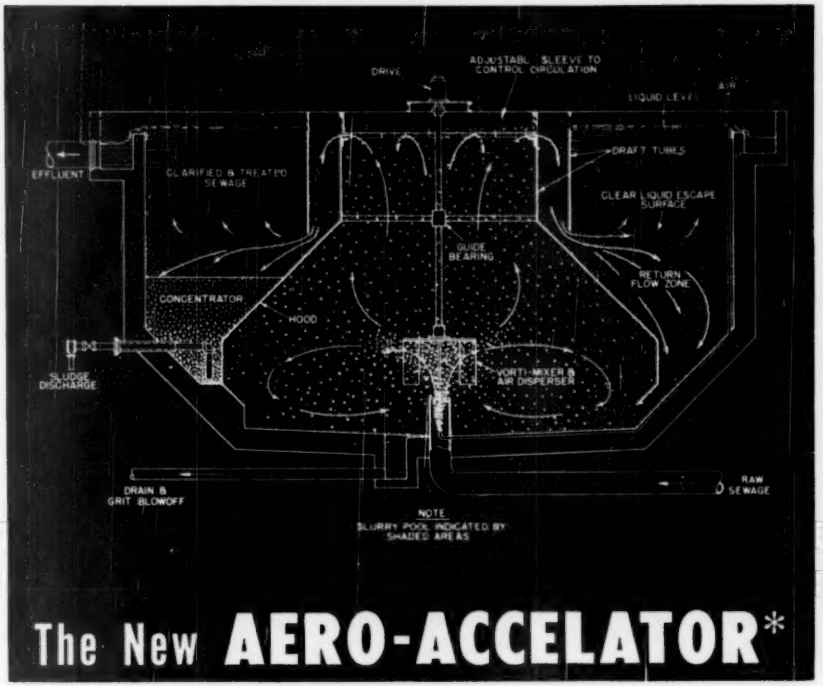

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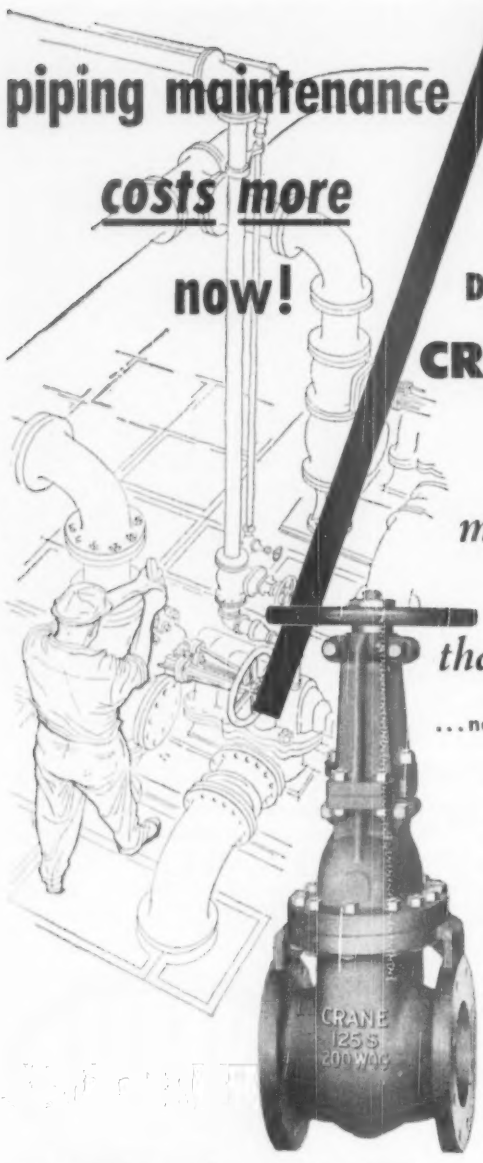

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A typical example of low-maintenance Crane Quality—No. 465½ 125-Pound Iron Body Gates. Rarely does the bonnet joint need attention. Flange construction includes reinforcement to prevent distortion and utilizes more bolts, more closely spaced than is usual in valves of this class. Crane precision-guided seating reduces seat and disc wear. Packing has long life because these valves have a deep stuffing box filled with high grade asbestos ring packing. A ball-type gland equalizes the packing load.

Better performance features like these make Crane the better buy in valves of every type. Ask your Crane Representative for a demonstration.

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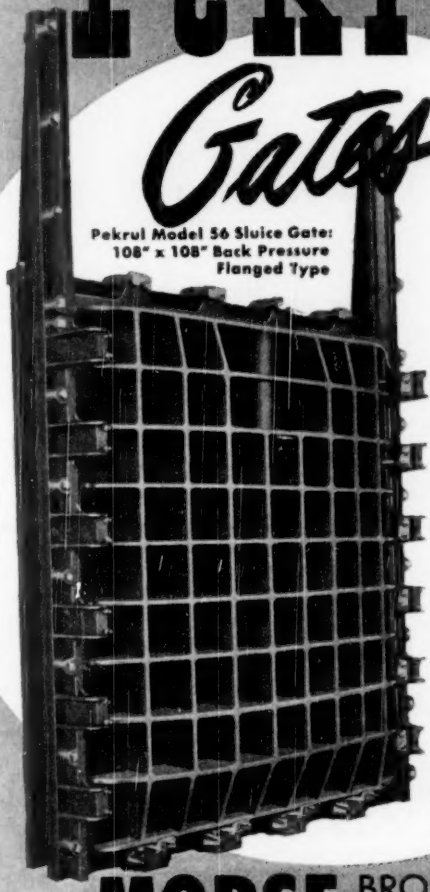

Pekrul Model 56 Sluice Gate:
108" x 108" Back Pressure
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MORSE BROS. MACHINERY
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Write for Catalog 49

BILL: *What d'ya mean, the boss gave you? The boss never gave anybody one of his favorite cigars.*

BOB: *It's this way. I happen to walk into the boss's office about something and there he is, pounding the desk at Joe because all the electrical conduit in the pump galleries has got to be replaced. Seems it's the second time in two years they've had to do it.*

BILL: *Well! What's he expect? Corrosion would lick anything in those galleries in two years.*

BOB: *That's what Joe said.*

BILL: *And what's all that got to do with that cigar?*

BOB: *Because just then I said why didn't they use conduit made of Everdur. Seems the Everdur we used for all our valve stems has been in so long they'd completely forgotten all about it.*

BILL: *Hmm. I see. Matter of fact, I'm surprised the boss didn't give you two cigars.*

Wherever corrosion is a problem, that's the place to consider EVERDUR*, as sewage and waterworks engineers everywhere can tell you.

This group of ANACONDA Copper-Silicon Alloys has long been foremost among corrosion-resisting metals—both for performance and for ease of fabrication. Everdur is available in all wrought commercial shapes and in casting ingots. It is readily welded.

If you need a tough, corrosion-resistant metal, let us show you how EVERDUR can help. The American Brass Company, Waterbury 20, Connecticut. In Canada, Anaconda American Brass Ltd., New Toronto, Ont.

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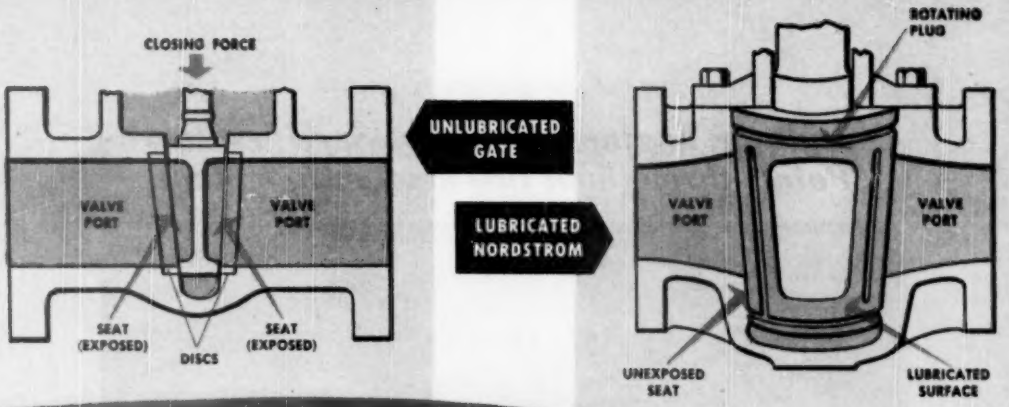
Where corrosion resistance counts—consider Everdur ANACONDA® Copper-Silicon Alloys



There's no substitute for lubrication in valves...

There are only two ways to get a seal between two metal surfaces within a valve:

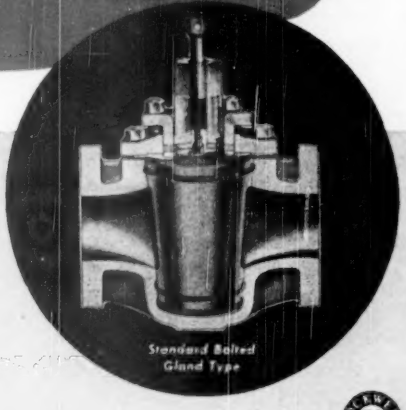
1. Force the seating surfaces together by distortion, which often involves excessive stresses and galling.
2. Use a plastic sealing medium between the surfaces.

Leakage and cutting is certain to occur where valve seats are exposed because line fluid carries abrasive elements that wear down the surface or eventually cut it.

But by using a plastic lubricant seal on the *unexposed* tapered seat of the Nordstrom valve, abrasion is avoided.

So when you install Nordstroms you stop abrasion. You then have valves that will last years longer; remain free from leakage; and turn easily. Never is it necessary to hammer-blow a Nordstrom. Lubricant hydraulically applied keeps the valve in perfect functional condition.

Switch to Nordstrom every time you replace an old valve.



Nordstrom Valves

NOW AUTOMATICALLY LUBRICATED WITH Hypermatic

Trade Mark Pats. Applied for

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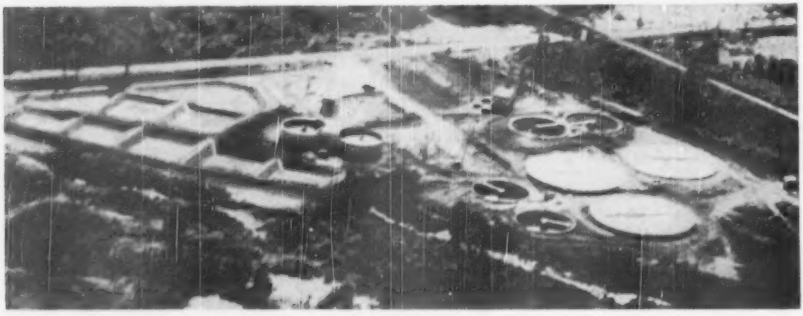
Atlanta, Boston, Chicago, Columbus, Houston, Kansas City, Los Angeles, New York, Pittsburgh, San Francisco, Seattle, Tulsa . . . and leading Supply Houses. Export: International Division, Rockwell Manufacturing Company, 7701 Empire State Bldg., New York 1, N.Y.

Consulting Engineer Haskins Specifies Inertol Paints throughout two new sewage plants



North Side Sewage Plant, the larger of the two plants at Joplin, Missouri.
Inertol colors and black bituminous paints applied throughout both plants.
Consulting Engineer: Charles H. Haskins, Kansas City.
Contractor for North Side Plant: Eby Construction Company, Wichita.
Contractor for South Side Plant: Lippert Brothers, Oklahoma City.

Stringent paint specifications for both Joplin plants

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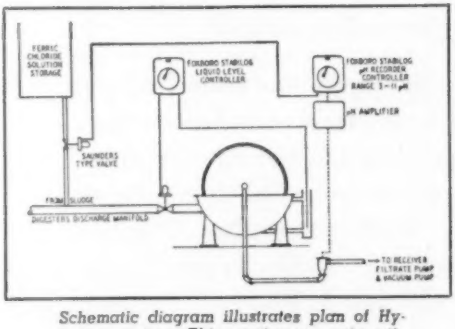
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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

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NEENAH-MENASHA, WIS.	✓			✓
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DULUTH, MINNESOTA			✓	✓
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C-E Raymond System at Duluth, Minn. Photo taken from operating floor showing part of furnace.

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Sewage Works

DISINFECTION OF SEWAGE WITH CHLORINE*

I. LABORATORY EXPERIMENTS ON THE EFFECT OF CHLORINE DOSAGE ON RESIDUAL COLIFORM ORGANISMS

By H. Heukelekian and Morris B. Smith

Efficieney of chlorination for bacterial kills generally has been measured in terms of percentage reduction, despite the fact that Clark and Gage (2) as early as 1911, and, later, Mallman and Shephard (6), pointed out that the safety of a chlorinated effluent must be based upon the actual numbers of bacteria remaining in the effluent and being discharged into the receiving body of water. If the bacterial numbers in the raw sewage were not variable, but uniform, then a fixed percentage reduction could yield an effluent with a definite number of bacteria. Such, however, is not the case; coliform organisms in sewages from different municipalities, as well as from the same municipality at different times, vary over a wide range (from 10,000 to 1,000,000 per ml.), depending on the dilution.

Recently, Eliassen *et al.* (3)(4) based their studies on the numbers of coliforms remaining in the effluent after chlorination. They concluded that residual chlorine should be used as a yardstick of the achievement of the desired objective of obtaining a definite number of coliform organisms in the effluent and that chlorine dosage is not a reliable method of control. Rudolfs and Ziemba (7) and, later, Allen and Brooks (1) reported that for doses lower than the chlorine demand, reduction in count depends not only on the proportion of the chlorine demand satisfied, but also on the absolute size of the dose. In view of the vagaries of chlorine demand determination, which is subject to many variables, a more positive and reliable method of control is still needed. The amperometric method of determining residual chlorine may be the answer, but to date a sufficient amount of work has not been done to establish a correlation between residuals obtained by this method and residual coliform organisms remaining. For these reasons it was considered of interest to determine whether a relationship could be established between the number of residual coliform organisms and chlorine dosage. Thus, the main objective of this paper is to formulate the chlorine dosages required to obtain stipulated residual coliform counts. The influence of other factors (such as contact time, effects of dilution of sewage, suspended solids, ammonia nitrogen, initial coliform count, and concentration of chlorine water used) was also studied using the same criteria; namely, chlorine dosage required to achieve stipulated residual coliform counts.

Methods

Settled sewage and trickling filter and activated sludge effluents were obtained from various municipal treatment plants in New Jersey. Different volumes of freshly prepared chlorine water of 200- to 1,000-p.p.m. concentration (except when otherwise stated) were added to portions of the samples and stirred with a glass rod. After the

* Paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University, New Brunswick, N. J.

expiration of the contact period, the samples were dechlorinated with sodium bisulfite. Coliform counts were made by using three tubes per dilution into lactose broth, followed by confirmation in brilliant-green tube broth. The bacterial counts are expressed as the most probable number (M.P.N.). Two contact periods, 5 and 30 minutes, were used throughout this work. The results are expressed as the p.p.m. chlorine required to give certain stipulated coliform residuals.

Halverson and Ziegler (5), in a mathematical analysis of the most probable number method for determining bacterial densities, indicated that where five tubes were employed per dilution it is 97 per cent certain that the M.P.N. is from 70 per cent below to 260 per cent above the actual value. Thus, for an M.P.N. of 100 per ml. the true value lies between 28 and 333 per ml. Dispersions of similar magnitude would be obtained for M.P.N. values of 10 and 1 per ml. It is apparent that for a single test with three tubes per dilution an M.P.N. of 100 per ml. is not discrete from an M.P.N. of 10 per ml., neither is an M.P.N. of 10 per ml. discrete from that of 1 per ml.

Averaging of the results from a number of tests under constant conditions has the effect of reducing the dispersion and of making the difference between M.P.N. values of 100 and 10 per ml., as well as of 10 and 1 per ml., significant. As it was not possible to perform a sufficient number of tests to accomplish this end, an additional method was resorted to. This involved modifying the stipulated residual counts downward to 30, 3, and 0.3 per ml. By doing this, the achievement of actual residual coliform counts of 100, 10, and 1 per ml. was assured, because for these M.P.N. values (30, 3, and 0.3) the upper limits of the dispersion ranges, which include the true value, lie at 100, 10, and 1 per ml., respectively. Therefore, the results presented include the chlorine dose required to yield confirmed stipulated coliform counts of 100, 30, 10, 3, 1, and 0.3 per ml. for each test. These individual results were obtained by plotting the logarithms of the remaining coliforms per ml. as ordinates and chlorine dosage, in p.p.m., as abscissa, then interpolating the dosage values corresponding to the stipulated residuals. In some cases, the dosages applied were not sufficient to yield the lowest desired stipulated residuals. In these cases, because experience indicated that this semilogarithmic plot always yielded a straight line, it was possible to extend the curves on the as-

TABLE I.—Characteristics of the Sewages Used and the Effect of Chlorine Dosage on Residual Coliform Organisms

	Desired Coliform Count (no./ml.)	Sewage I		Sewage II
Contact time (min.)		30	5	30
No. tests		11	8	6
Chlorine demand (p.p.m.)		3.4	2.7	9.0
Initial coliforms (no./ml.)		90,000	144,000	216,000
NH_3—Nitrogen (p.p.m.)		13	12	—
Susp. solids (p.p.m.)		60	50	—
Cl_2 required to produce an effluent with desired coliform count (p.p.m.)	100	1.1–3.0	3.6–5.5	1.7–3.7
	30	1.3–3.5	4.2–7.5	1.8–4.4
	10	1.6–3.9	4.7–8.7	1.9–5.6
	3	1.7–4.5	5.1–9.5	2.0–7.0
	1	1.9–5.1	6.0–11.2	2.2–7.8
	0.3	2.1–6.1	6.6–13.1	2.7–8.7

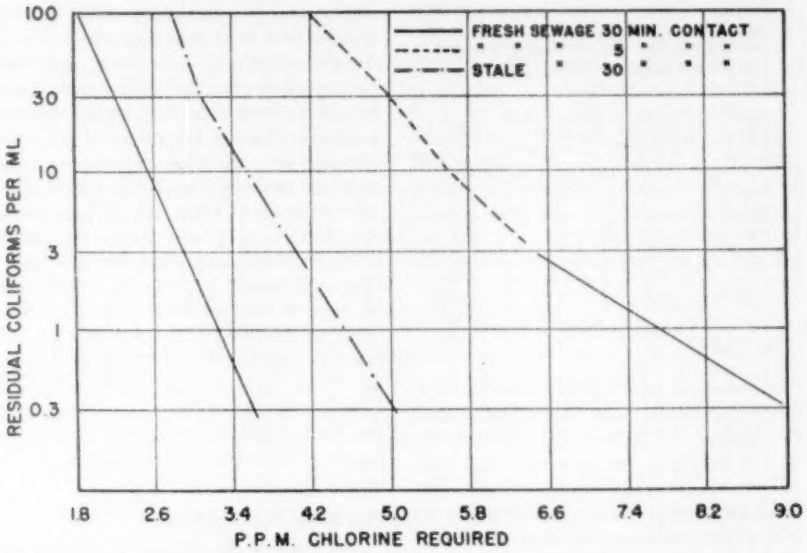

FIGURE 1.—Chlorine dosage required to produce an effluent with various numbers of residual coliform organisms at different contact times with fresh and stale settled domestic sewage.

sumption of a straight line relationship and thus obtain the desired values.

Results

Relation of Chlorine Dosage to Residual Coliform Organisms

For the work on the relationship between chlorine dosage and the number of residual coliform organisms, settled sewage from two different plants was used. Eleven separate samples were employed with 30-min. contact time and eight samples from the same plant for 5-min. contact time. From the second plant, only 30-min. contact time studies were made on six separate samples. The pertinent data on the average characteristics of the sewages employed are given in Table I, together with the range (minimum and maximum) of chlorine dosages required to produce a residual coliform count of 100, 30, 10, 3, and 1 per ml. For a sewage from a given plant and with constant contact time there is a wide range of chlorine required to produce an effluent with a given density of coliform organisms and a considerable amount of overlapping occurs. However, the amount of chlorine required increases, generally, for effluents with lower coliform densities. It is apparent that the amount of chlorine required to produce a given residual coliform count is greater for a 5-min. contact time than for a 30-min. contact time. Finally, settled sewage from plant 2 required considerably more chlorine to produce a given residual coliform count than settled sewage from plant 1 (with equal contact time).

The arithmetical average coliform residuals for each of these experiments are plotted on logarithmic scale against the dosage of chlorine required (Figure 1). It is apparent that a greater amount of chlorine is required to produce an effluent with lower residual coliform counts and that there is a di-

TABLE II.—Comparison of 5-Min. and 30-Min. Contact Period Chlorine Requirements of Settled Sewage for Obtaining Various Stipulated Residual Coliform Numbers

Stipulated Coliform Residuals (no./ml.)	30-Minute Chlorine Requirement (p.p.m.)	5-Minute Chlorine Requirement (p.p.m.)	Ratio, 30-Min. to 5-Min. Requirement[1]
100	1.8	4.2	1:2.3
30	2.1	5.0	1:2.4
10	2.5	5.6	1:2.2
3	2.8	6.5	1:2.3
1	3.2	7.8	1:2.4
0.1	3.7	9.0	1:2.4

[1] Average, 1:2.3.

rect relationship between the desired bacterial numbers in the effluent and the dosage. However, this relationship is not constant for sewages with different characteristics and from different sources. Hence, chlorination of sewage practiced on the basis of dosage alone cannot meet the requirement at all times of producing an effluent of a given coliform density. Table II shows the relationship between contact time and the amount of chlorine required to produce stipulated numbers of coliform organisms. It is apparent that the amount of chlorine required is 2.2 to 2.4 times higher for 5-min. contact time than for 30-min. contact time and is independent of whether 1 or 3 residual coliforms per ml. are to be obtained.

Relation of Initial Numbers of Coliforms to Chlorine Dosage Required to Obtain a Stipulated Number in the Effluent

The results analyzed on the basis of the effect of the initial numbers of coliform organisms on the amount of chlorine required to yield a stipulated number of 10 coliform organisms per ml. of effluent showed that there was no consistent relationship.

Effect of Sewage Dilution on Chlorine Requirement to Produce Stipulated Numbers of Coliforms

The chlorine requirements to produce stipulated numbers of coliform organisms in undiluted and diluted sewage, and with dilution ratio of 1:5, were determined for 5-min. and 30-min. contact periods. The results (Table III) show that for 5-min. contact period a dilution of sewage 1 to 5 decreases the chlorine requirement to produce various stipulated numbers of coliforms more than one-half, whereas for 30-min. contact period the same dilution results in reducing the chlorine requirement to about one-fourth of that of the original sewage. The ratio of chlorine required by the diluted sewage in 5-min. to 30-min. contact time is 1 to 3.3. The effect of dilution, therefore, appears to increase the importance of contact time as a means of reducing the chlorine requirements.

Trickling Filter Effluent

An attempt was made to determine the effect of treatment of sewage by trickling filters on the amount of chlorine required to produce a stipulated number of coliform organisms. This was accomplished by diluting the settled sewage from the same plant from

TABLE III.—Comparison of Average Chlorine Requirements for Obtaining Stipulated Coliform Residuals with Diluted and Undiluted Sewage

Contact Time (min.)	Stipulated Coliform Residuals (no./ml.)	Chlorine Requirement (p.p.m.)		Ratio of Cl_2 of Diluted to Undiluted[2]
		Diluted Sewage[1]	Undiluted Sewage	
5	100	1.53	3.8	1:2.5
	30	1.79	4.4	1:2.5
	10	2.17	5.0	1:2.3
	3	2.56	5.7	1:2.2
	1	2.91	6.7	1:2.3
	0.3	3.30	7.6	1:2.4
30	100	0.47	1.9	1:4.0
	30	0.54	2.2	1:4.1
	10	0.66	2.5	1:3.8
	3	0.79	2.9	1:3.7
	1	0.89	3.3	1:3.7
	0.3	0.99	3.9	1:3.9

[1] 1 part sewage and 4 parts water.

[2] Average for 5-min. contact, 1:2.4; for 30-min. contact, 1:3.9.

which the trickling filter effluent was obtained to approximately the same suspended solids content as the effluent and by determining the chlorine required to produce various stipulated numbers of coliforms after 5-min. and 30-min. contact periods. Three such series were made, but only the average values are presented.

The average characteristics of the samples were as follows:

Contact Period (min.)	Filter Effluent			Diluted Sewage		
	Susp. Sol. (p.p.m.)	NH_3-N (p.p.m.)	Coliforms (no./ml.)	Susp. Sol. (p.p.m.)	NH_3-N (p.p.m.)	Coliforms (no./ml.)
30	11.7	25	2,200	8.7	6.5	21,500
5	10	19	4,500	8	6	7,000

Although the suspended solids content of the diluted sewage was adjusted to approximately that of the filter effluent, the other characteristics (such as NH_3-N and initial coliforms) could not be adjusted by dilution to equal values. The average results of the chlorination studies of the diluted sample of sewage and filter effluent (Table IV) show that for 30-min. contact time the amount of chlorine required to give various numbers of stipulated coliform organisms is about the same in the filter effluent as in the diluted sewage. For 5-min. contact time, appreciably more chlorine is required to achieve a certain number of stipulated coliform organisms from the filter effluent than to achieve the same number in the diluted sewage. It is possible only to speculate as to the cause and significance of the results. The difference between the effect of 5-min. and 30-min. contact times on the chlorine requirement of filter effluent and diluted sewage to achieve a certain residual coliform number cannot readily be attributed to the higher values of ammonia nitrogen in the filter effluent than in the diluted sewage, because the ammonia nitrogen content of the filter effluent was higher than that of the diluted sewage for both contact periods. Neither can it be ascribed to the differences in the initial coliform numbers, because for both contact periods the numbers in the filter effluent samples were lower than in the diluted sewage, nor to the differences in the suspended solids concentration or character of the sewage.

Activated Sludge Effluent

Three series of tests with 30-min. and 5-min. contact periods were made to determine the chlorine dosage required to produce various stipulated

TABLE IV.—Chlorine Required to Obtain Stipulated Coliform Residuals of Diluted Sewage and Trickling Filter Effluent

Stipulated Coliform Residual (no./ml.)	Filter Effluent			Diluted Sewage		
	30-Min. Cl_2 Requirement (p.p.m.)	5-Min. Cl_2 Requirement (p.p.m.)	Ratio, 30-Min. to 5-Min. Requirement	30-Min. Cl_2 Requirement (p.p.m.)	5-Min. Cl_2 Requirement (p.p.m.)	Ratio, 30-Min. to 5-Min. Requirement
100	0.81	2.64	1:3.3	0.8	1.91	1:2.4
30	0.94	3.06	1:3.3	0.9	2.18	1:2.4
10	1.09	3.48	1:3.2	1.02	2.45	1:2.4
3	1.29	4.17	1:3.2	1.23	3.06	1:2.5
1	1.53	5.19	1:3.4	1.43	3.50	1:2.5
0.3	1.78	6.57	1:3.7	1.65	3.84	1:2.3

TABLE V.—Chlorine Requirements for Obtaining Stipulated Coliform Residuals with Activated Sludge Effluent

Stipulated Coliform Residuals (no./ml.)	Chlorine Required (p.p.m.)		Ratio of 30-Min. to 5-Min. Requirement
	30-Min. Contact	5-Min. Contact	
100	0.23	1.22	1:5.3
30	0.60	2.11	1:3.5
10	0.90	2.81	1:3.1
3	1.30	3.73	1:2.9
1	1.71	4.60	1:2.7
0.3	1.96	5.89	1:3.0

residual coliform organisms with activated sludge effluents. The results (Table V) show that the amount of chlorine required increases regularly for lower residual coliform organisms with both 5-min. and 30-min. contact time and that chlorine required for 5-min. contact time to produce an equal number of coliform organisms is much higher than for 30-min. contact. The ratio of chlorine required for 30-min. and 5-min. contact times decreases from 1:5.3 to produce 100 coliforms per ml. to 1:3.0 to produce numbers of 10 per ml. or less.

Effect of Chlorine Water Concentration on Dosage Required to Yield Stipulated Coliform Residuals

Figure 2 illustrates the effect of the strength of chlorine solution on the amount of chlorine required to produce various stipulated coliform organism counts with a 5-min. contact time. With higher concentration of chlorine solution (5,000 p.p.m.), higher amounts of chlorine were required than for lower concentrations of 200 to 1,000 p.p.m. The results with the higher concentration of chlorine solution are the averages of 4 runs; those with the lower concentration represent the average of 11 runs. The sewages for this comparison were obtained from the same source, but not necessarily at the same time. As the differences in the amount of chlorine required are appreciable, the effect might be attributed to a greater loss of chlorine from more concentrated solution or to a greater immediate localized consumption.

Discussion

The first generalization that arises from this study is that the control of

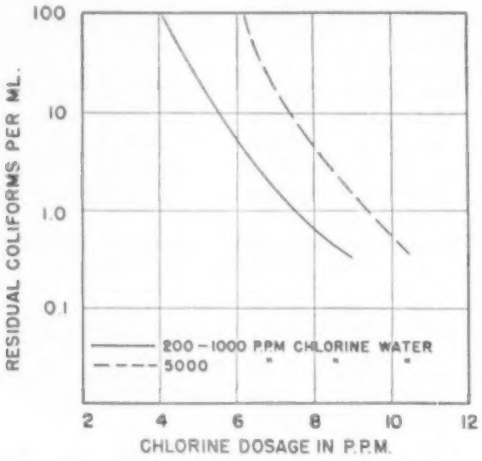

FIGURE 2.—Effect of the concentration of chlorine solution used on the dosage of chlorine required to produce an effluent with various numbers of residual coliform organisms.

chlorination cannot be based on the dosage of chlorine, because neither for sewages from different sources, nor for a sewage from a given source but at different times, does a constant dosage of chlorine produce a given number of coliform organisms per ml. in the effluent. Naturally, a high chlorine dosage may be maintained to accomplish the purpose at all times, but this would be economically unsound. It is true that for a given sewage the percentage of bacterial kills increases with increasing dosage of chlorine up to the residual, as has been shown by Rudolfs and Ziemba (7) and Allen and Brooks (1). There are, however, differences in the actual percentage reductions of coliform organisms with a given chlorine dosage for different sewages, even at the subresidual levels of chlorination. It follows that, to obtain a certain stipulated number of coliforms after chlorination, the dosage should be sufficient to give a certain chlorine residual, as pointed out by Eliassen *et al.* (3) on the basis of laboratory experiments and as will be shown in a subsequent paper of this series on the basis of plant experiments.

The lack of correlation between dosage and the desired bacterial quality of effluent is to be attributed to variations in the chlorine demand of different sewages. Chlorination of sewages with a high chlorine demand results in a failure to obtain residual chlorine with a dosage of chlorine sufficient to give a residual with other sewages. The specific nature of compounds in sewage which react with chlorine and reduce the efficiency of bacterial kills is obscure. It is generally known that sewage contains organic and inorganic constituents, which react with chlorine. The reaction products may not possess germicidal properties or may act more slowly than free chlorine. Chloro-proteins and chloro-peptone have been shown by Rudolfs and Ziemba (7) to have no inhibitory effect on bacteria. Hydrogen sulfide reacts with chlorine to produce a non-germicidal product. Chloramines and simple organic chloramines have a definite germicidal activity. It is the more effective utilization of the germicidal activity of chloro-products which makes significant the value of increased contact time in achieving stipulated coliform residuals, even with 100 per cent or more satisfaction of chlorine demand. The characteristics and concentration of interfering substances not giving products of germicidal activity determine the dosage required to achieve a stipulated coliform residual. Suspended solids, ammonia-nitrogen, and initial bacterial counts do not appear to play a major role in determining the chlorine requirements for obtaining stipulated coliform residuals. Contact time plays an important role in the achievement of the desired bacterial objectives. For any chlorine dosage, the greater the contact time, the lower are the residual numbers of coliform organisms. The increased kill resulting from increased contact time is due to the action of chloro-compounds formed as a result of the reaction between chlorine and sewage components, which are slower-acting germicides than free chlorine.

The dilution of sewage decreases the dosage of chlorine required, but not in direct proportion to the degree of dilution. A dilution of 1:5 decreases the chlorine required by 1:2.5 with 5-min. contact time and by 1:3.9 with 30-min. contact time. The reaction between chlorine and sewage components apparently goes more nearly to completion in dilute sewage and thereby requires relatively more chlorine for a given kill or produces less kill for a given amount of chlorine.

The experiment in which the suspended solids concentration of settled sewage was reduced by dilution to the same value as in the trickling filter effluent from the same plant indicates that for a 30-min. contact period chlorine requirements for equivalent coli-

form residuals are practically the same for settled diluted sewage as for trickling filter effluent. For a 5-min. contact time the trickling filter effluent required appreciably more chlorine for equivalent kills than did the diluted sewage. Contact time also seems to be an important factor in this respect.

Finally, a comparison of the chlorine requirements of settled sewage, trickling filter effluent, and activated sludge effluent for stipulated number of coliform organisms (Figure 3) shows that for both 5-min. and 30-min. contact periods stale sewage required more chlorine than fresh sewage, which in turn required greater dosages than either the activated sludge or trickling filter effluents; the last two required approximately the same chlorine quantities. The influence of interfering substances is reflected here.

Summary and Conclusions

Laboratory experiments were conducted to determine the quantity of chlorine required to produce an effluent with various stipulated numbers of residual coliform organisms in fresh and stale sewage, and trickling filter and activated sludge effluents. The effect of contact time, dilution of sewage, initial number of coliform organisms, and concentration of chlorine solution applied was studied.

The results indicate that:

1. The achievement of stipulated residual coliform organisms cannot be based on chlorine dosage, as there is a considerable variation in the amount of chlorine required to accomplish this objective with different samples of sewage from the same source.

2. The amount of chlorine required increases regularly for the accomplishment of lower numbers of residual coliform organisms.

3. The amount of chlorine required to achieve certain stipulated numbers of residual coliform organisms in settled sewage with 30-min. contact time is less than half of that required for the same residual count with 5-min. contact time.

4. Stale sewage requires more chlorine than fresh sewage for the same stipulated residual counts with the same contact period.

5. Nearly the same amount of chlo-

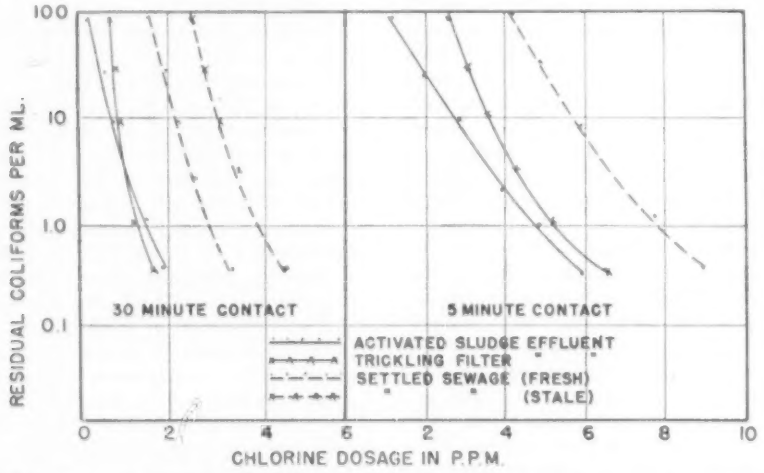

FIGURE 3.—Amount of chlorine required to obtain stipulated numbers of coliform organisms with different types of effluents.

rine is required to achieve given counts of residual coliforms in activated sludge and trickling filter effluents; this amount is lower than that required to yield the same count in settled sewage.

6. Dilution of sewage with water in the ratio of 1:4 decreases the chlorine required to achieve stipulated coliform residuals by one-half with 5-min. contact time and by nearly one-fourth with 30-min. contact time.

7. Dilution of settled sewage to the same suspended solids concentration as the effluent from the trickling filter results in the same amount of chlorine required to achieve a stipulated coliform organism residual with 30-min. contact time. With 5-min. contact time, filter effluent required somewhat more chlorine to give the same residual coliform organism count than did the diluted sewage.

8. There is no correlation between the initial count of coliform organisms and the amount of chlorine required to achieve a stipulated residual coliform organism count.

9. A greater amount of chlorine is required to achieve a stipulated residual coliform organism count when chlorine solution used has a concentration of 5,000 p.p.m. of chlorine than with 200 to 1,000 p.p.m. of chlorine.

Acknowledgment

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References

1. Allen, L. A., and Brooks, E., "Destruction of Bacteria in Sewage and Other Liquids by Chlorine and by Cyanogen Chloride." *Jour. of Hyg.* (Brit.), **47**, 320 (1949).
2. Clark, H. W., and Gage, S. D., "Experiments Upon the Disinfection of Sewage and the Effluents from Sewage Filters." Mass. State Board of Health, 43rd Ann. Rep., p. 339 (1911).
3. Elliassen, R., Heller, A. N., and Krieger, H. L., "A Statistical Approach to Sewage Chlorination." *Sewage Works Jour.*, **20**, 6, 1008 (Nov., 1948).
4. Elliassen, R., and Krieger, H. L., "Control of Bacterial Numbers in Chlorinated Sewage Effluents." THIS JOURNAL, **22**, 1, 47 (Jan., 1950).
5. Halverson, H. O., and Ziegler, N. R., "Application of Statistics to Problems in Bacteriology. III. A Consideration of the Accuracy of Dilution Data Obtained by Using Several Dilutions." *Jour. Bact.*, **26**, 559 (1933).
6. Mallman, W. L., and Shephard, W. F., "Disinfection of Sewage with Minimum Amounts of Chlorine." *Mich. Eng. Exp. Sta. Bull.* 64, p. 21 (1935).
7. Rudolfs, W., and Ziemba, J. W., "The Efficiency of Chlorine Dosage in Sewage Disinfection as Affected by Certain Environmental Factors." *Jour. Bact.*, **27**, 419 (1934).

ACTIVATED SLUDGE STUDIES

II. EFFICIENCY AND PERFORMANCE UNDER VARIOUS OPERATING CONDITIONS

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In a preceding publication (1), studies involving the addition of unaerated activated sludge to settled sewage without further aeration were discussed. These studies have been supplemented by additional experiments. In the original work, the concentration of suspended solids in the mixture of sewage and sludge was maintained at approximately 1,000 p.p.m.; 5-day B.O.D. removals varying from about 2 to 21 per cent were obtained. These tests have since been supplemented by maintaining suspended solids concentrations of approximately 500, 1,000, 2,000, and 3,000 p.p.m. in the mixed liquor. The activated sludge, which was obtained at the Back River sewage treatment works serving Baltimore City, was mixed with settled sewage for 3 min. During this period no effort was made to exclude air from the surface of the mixtures, as the mixing period was of short duration. Each mixture was allowed to settle for 2 hr. Neither the sludge nor the mixtures were aerated.

Several groups of tests were made, three of which are reported herein (Table I and Figure 1). There was considerable variation in the results obtained. In each case there was a decrease in the 5-day B.O.D. removal as the solids concentration in the mixed liquor increased, although this decrease was small in the case of the tests in Group 3, when the suspended solids were increased from 500 to 2,000 p.p.m. The 5-day B.O.D. of the sewage was reduced from 164 p.p.m. to 86.9 p.p.m. in one instance and 85.9 p.p.m. in the other, a reduction of about 47.0 per cent without the use of air. Although the removal of B.O.D. became less as the concentration of suspended solids in the mixed liquor was increased, the suspended solids did not correspondingly decrease. For example, in the case of the tests included in Group 1, the average suspended solids removals were 32.4 and 34.1 per cent when there were 501 and 3,005 p.p.m. of suspended solids, respectively, in the mixed liquor. It is believed that the explanation for the lack of correspondence between the removal of the B.O.D. and suspended solids from the sewage with different concentrations of suspended solids in the mixed liquor is that, as the concentration of the latter solids is increased, a greater amount of soluble B.O.D. diffuses into the liquid phase of the sewage-sludge mixture and counteracts the B.O.D. that is removed by the sedimentation of the solids in the sewage.

That activated sludge is capable of reducing the concentration of suspended solids in sewage without the addition of air is indicated by the investigations of Baker (2), Heukelekian (3), and others. The work described in this paper shows that both the removal of suspended solids and B.O.D. is considerable and may vary with the character of the activated sludge. Mixed liquor with a low concentration of suspended solids gave a better B.O.D. removal than a high concentration. On the other hand, the removal of suspended solids from sewage was about the same whether a high or a low concentration was used. Although

the reduction by oxidation of some of the B.O.D. of the sewage used in these experiments cannot be entirely ruled out, it is believed that the major portion of the reduction is due to adsorption and flocculation phenomena.

Effect of Preaerating Sludge

A second set of experiments consisted in determining the effect of various periods of preaeration and of different concentrations of suspended solids in the mixed liquor on the B.O.D. reduction in sewage. Samples of activated sludge were preaerated for ½, 1, 2, and 3 hr. Settled sewage was then added to the samples in such amounts that the suspended solids in the mixture amounted to approximately 500, 1,000, 2,000, and 3,000 p.p.m. The sewage and the sludge were mixed thoroughly but gently for 3 min., during which time no air was added. After the sludge had settled for 2 hr., the supernatant was siphoned off and its 5-day B.O.D. and suspended solid content were determined. The results are given in Figures 2, 3 and 4.

TABLE I.—Removal of B.O.D. and Suspended Solids from Sewage by Mixing It with Activated Sludge for 3 Minutes and Settling for 2 Hours (Mixture Not Aerated)

Suspended Solids in Mixed Liquor (p.p.m.)	5-Day B.O.D.				Suspended Solids			
	Untreated Sewage (p.p.m.)	Treated Sewage (p.p.m.)	Removal (%)	Removal Av. (%)	Untreated Sewage (p.p.m.)	Treated Sewage (p.p.m.)	Removal (%)	Removal Av. (%)
				(a) Group 1				
501	104.0	78.0	25.0	25.9	92	63	31.5	32.4
501	115.6	84.7	26.7		90	60	33.3	
997	104.0	85.0	18.3	20.4	92	60	34.8	35.2
999	115.6	89.7	22.4		90	58	35.6	
1,991	104.0	98.0	5.8	5.9	92	61	33.7	33.5
2,001	115.6	108.7	6.0		90	60	33.3	
3,007	104.0	102.0	1.9	2.3	92	60	34.8	34.1
3,002	115.6	112.7	2.5		90	60	33.3	
				(b) Group 2				
502	99.6	81.6	18.1	18.3	70	57	18.6	16.5
502		81.2	18.4		70	60	14.3	
1,003		89.6	10.1	9.8	70	55	21.4	19.3
1,003		90.2	9.4		70	58	17.1	
2,006		95.6	4.0	4.7	70	56	20.0	20.0
2,006		94.2	5.4		70	56	20.0	
3,003		97.6	2.0	1.2	70	55	21.4	19.3
3,003		99.2	0.4		70	58	17.1	
				(c) Group 3				
503	164	86.9	47.0	47.3	165	56	66.1	66.4
501		85.9	47.6		165	55	66.7	
1,004		94.9	42.1	43.4	165	86	47.9	47.6
1,002		90.9	44.6		165	87	47.3	
1,998		88.9	45.8	46.1	165	50	69.7	69.1
1,998		87.9	46.4		165	52	68.5	
3,000		105.8	35.4	34.5	165	82	50.3	49.7
3,001		108.9	33.6		165	84	49.1	

The removal of B.O.D. and suspended solids decreased as the concentration of suspended solids in the mixed liquor was increased. In the case of 1-hr. preaeration, the B.O.D. removal decreased from 22.3 to 5.1 per cent with a corresponding increase of suspended solids in the mixed liquor from 500 to 3,000 p.p.m. The removal of B.O.D. increased as the preaeration period increased. For example, with a concentration of approximately 1,000 p.p.m. of suspended solids in the mixed liquor the B.O.D. removal increased from 7.9 to 27.9 per cent with an increase in aeration from 0.5 to 3 hr.

The removal of suspended solids from the sewage followed the same general pattern as the removal of B.O.D. The amount of suspended solids removed varied directly as the length of the aeration period and inversely as the amount of suspended solids in the mixed liquor.

Effect of Aeration Period and Suspended Solids in Mixed Liquor on B.O.D. Removal

Numerous attempts have been made to formulate the relationship between the B.O.D. removal in sewage by the activated sludge process and such factors as the aeration period, the amount of suspended solids in the mixed liquor, the quantity of air used, and other parameters (4) (5) (6) (7) (8) (9) (10). The complexity of the problem becomes apparent when the number of factors that affect the performance of activated sludge plants is considered. In addition to the three foregoing governing factors, there are others, such as

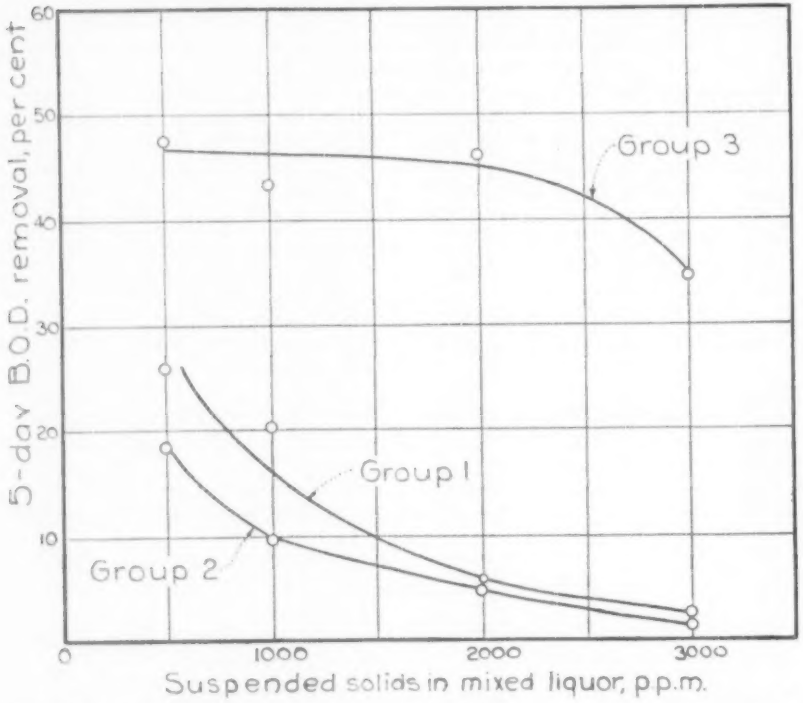

FIGURE 1.—Relationship between the suspended solids in sewage-activated sludge mixture and reduction in B.O.D. of sewage (mixture, not aerated, settled for 2 hr.).

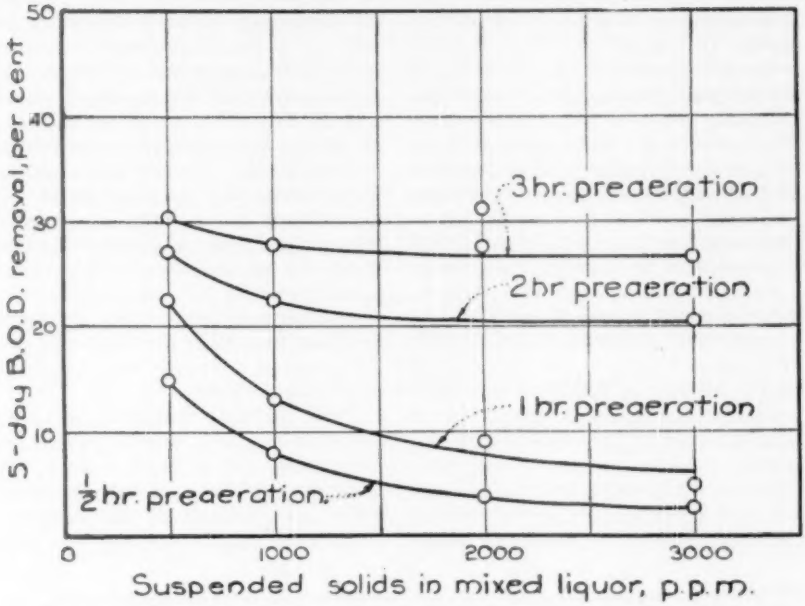

FIGURE 2.—Effect of suspended solids in mixed liquor and preaeration of activated sludge on B.O.D. reduction in sewage (unaerated mixed liquor settled for 2 hr.).

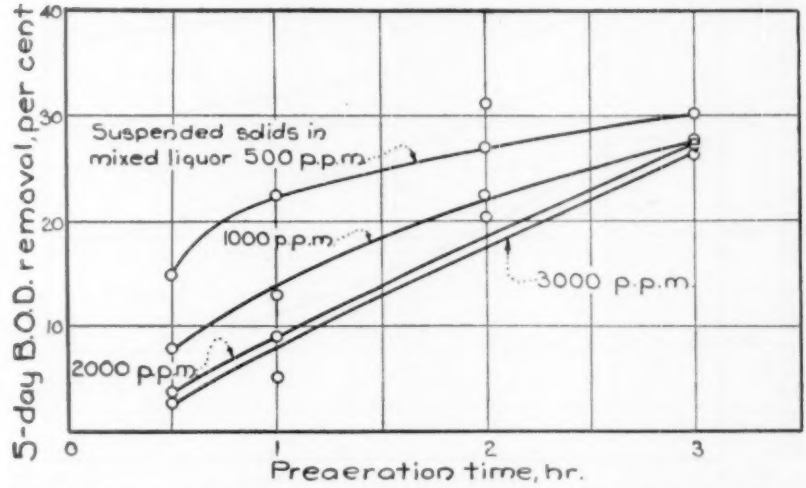

FIGURE 3.—Relationship between B.O.D. reduction in sewage and preaeration period of activated sludge with various amounts of suspended solids in mixed liquor (unaerated mixed liquor settled for 2 hr.).

the age, temperature, pH value, oxidation-reduction potential, and oxygen uptake of the sludge. The numbers and types of bacteria and protozoa and the enzymes secreted by these organisms play a major role in the process. Furthermore, the characteristics of the sewage are important. The amounts of fixed solids and grease in the sewage undoubtedly affect the results. Furthermore, small amounts of iron have been reported to stimulate the process.

Several hundred tests were made to determine the effect of varying the aeration period and the concentration of suspended solids in the mixed liquor on the removal of B.O.D. from settled sewage. The results of only a few of these tests are given. As was to be expected, numerous inconsistencies were observed. Although all of the reasons for these inconsistencies are not known, the differences in the flora and fauna of the activated sludge were perhaps the chief cause of the divergence in the results. It should be remembered that the B.O.D. determination, which was used to evaluate the results, does not give an exact measure of the strength of sewage and is subject to numerous biological and biochemical vagaries. When attempting to determine the effect of such factors as the strength of the sewage being treated, the aeration time, and the suspended solids in the mixed liquor on the removal of B.O.D., the average analyses of an extensive group of tests must be made, as a single group of tests may vary considerably from the norm.

Fresh activated sludge was added to settled sewage in such amounts that approximately 100, 200, 500, 1,000, 2,000, 2,600, and 3,000 p.p.m. of suspended solids were present in the mixtures. These were aerated for 0.25, 0.5, 1, 2,

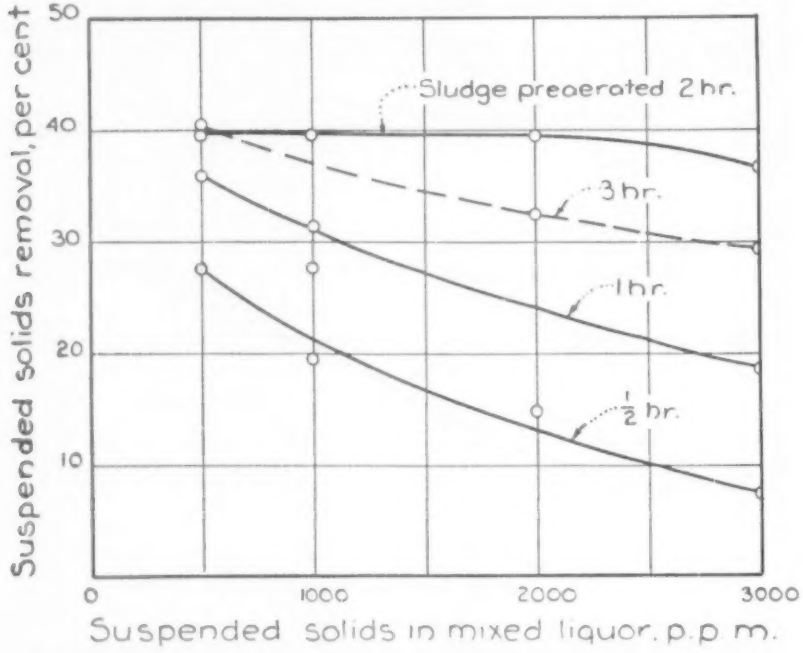

FIGURE 4.—Suspended solids removal from sewage by preaerated activated sludge (unaerated mixed liquor settled for 2 hr.).

and 6 hr., then allowed to settle for 2 hr. The 5-day B.O.D. and suspended solids in the sewage before aeration and after settling were determined. A summary of the results is given in Table II and Figure 5. With a 15-min. aeration period the average B.O.D. removal varied from 63.0 to 72.0 per cent. A 1-hr. aeration period gave average removals ranging from 76.8 to 87.8 per cent; 6-hr. aeration gave, with one exception, an average removal of over 90 per cent. When the suspended solids in the mixed liquor were 3,000 p.p.m. and the aeration period was 1 hr. or less, the B.O.D. and suspended solids removals were, in general, less than the removals when the solid concentrations were 2,000 p.p.m. or less.

The following is believed to be the reason for this condition. When activated sludge is added to sewage that is being aerated, there is some breakdown of the sludge flocs with the dispersion

TABLE II.—B.O.D. and Suspended Solid Reductions in Sewage by the Activated Sludge Process Due to Various Aeration Periods and Suspended Solid Concentrations in the Mixed Liquor

Susp. Sol. in Mixed Liquor[1] (p.p.m.)	5-Day B.O.D. Removed			Susp. Solids Removed (%)	Loading (lb. B.O.D./day/1,000 lb. of susp. sol./hr. of aeration)	Groups of Tests Made
	Av. (%)	Max. (%)	Min. (%)			
(*a*) 15-MIN. AERATION PERIOD						
500	69.3	71.1	67.0	53.5	730	6
1,000	70.7	73.1	67.0	66.4	364	6
2,000	72.0	75.2	68.3	57.6	182	6
3,000	63.0	66.9	53.1	44.2	122	6
(*b*) 30-MIN. AERATION PERIOD						
500	73.8	78.5	68.9	68.8	337	6
1,000	78.7	81.1	74.0	74.6	168	6
2,000	76.8	81.7	71.5	74.7	84	6
3,000	66.6	70.3	61.5	62.6	56	6
(*c*) 60-MIN. AERATION PERIOD						
500	76.6	81.4	72.1	67.4	182	6
1,000	83.8	88.5	79.2	79.1	91	6
2,000	87.8	91.7	85.1	94.5	46	6
3,000	84.0	89.0	76.4	88.6	30	6
(*d*) 2-HR. AERATION PERIOD						
100	63.6	79.1	34.5	55.5	706	12
200	79.6	90.4	73.2	85.3	357	13
500	85.7	96.1	66.1	84.3	145.5	36
2,600	95.5	98.8	92.2	97.2	29.3	11
(*e*) 6-HR. AERATION PERIOD						
100	84.7	92.0	79.4	78.0	238	12
200	90.9	96.6	66.4	97.1	117	13
500	94.2	98.6	86.3	94.8	48	36
2,600	95.7	98.7	91.2	99.0	9.8	11

[1] Approximate.

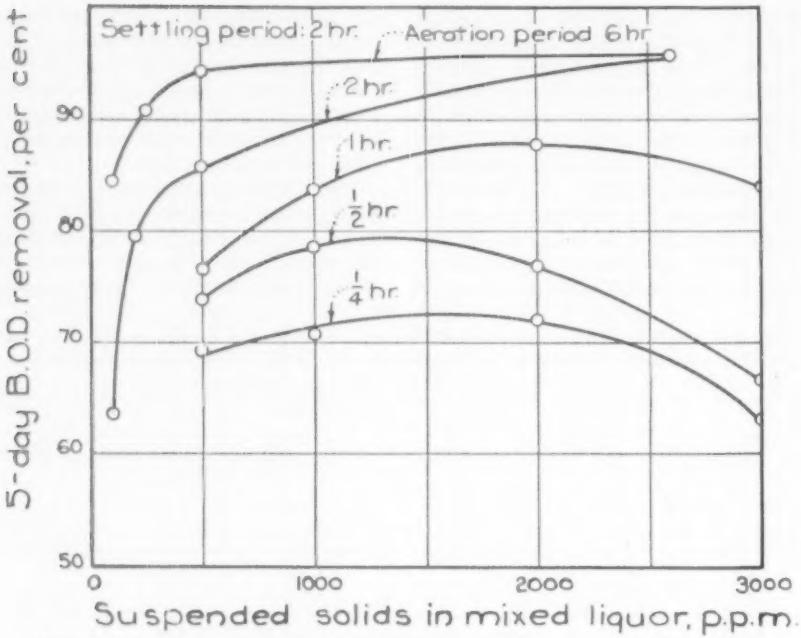

FIGURE 5.—Effect of aeration period and suspended solids in mixed liquor on B.O.D. removal.

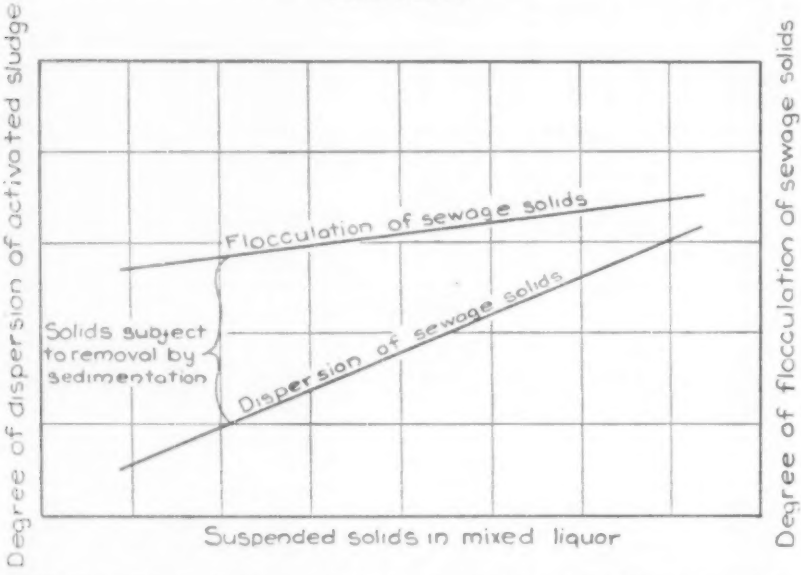
Degree of dispersion of activated sludge
Flocculation of sewage solids
Solids subject to removal by sedimentation
Dispersion of sewage solids
Suspended solids in mixed liquor
Degree of flocculation of sewage solids

FIGURE 6.—Relationship between dispersion of activated sludge solids and flocculation of sewage solids with varying concentrations of suspended solids in mixed liquor.

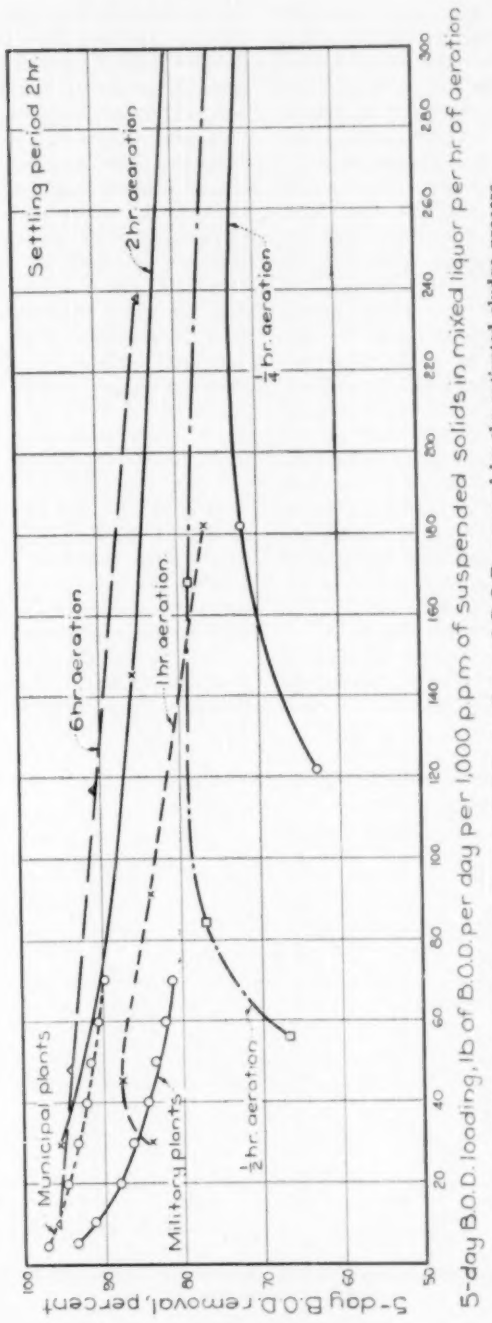
Setting period 2hr
6hr aeration
2hr aeration
1hr aeration
½hr aeration
¼hr aeration
Municipal plants
Military plants
5-day B.O.D. removal, percent
5-day B.O.D. loading, lb of B.O.D. per day per 1,000 p.p.m. of suspended solids in mixed liquor per hr of aeration

FIGURE 7.—Relationship between B.O.D. loading and B.O.D. removal by the activated sludge process.

of colloidal and suspended materials into the liquid phase. This dispersion is proportionate to the concentration of activated sludge in the mixed liquor. At the same time, the reverse action is taking place; that is, the sludge flocs are flocculating and adsorbing materials from the sewage. The excess of suspended solids that are flocculated from the sewage over those that are dispersed by aeration represents, in general, the solids that can be removed from the system by sedimentation. This excess is greater when the suspended solids content in the mixed liquor is low than when it is high. Therefore, the rate of change in the removal by flocculation of solids from sewage with increasing amounts of suspended solids in the mixed liquor is less than the rate of change in the dispersion of solids by aeration from the activated sludge with corresponding increases in the amount of suspended solids in the mixed liquor. This relationship is represented graphically by Figure 6.

The relationship between the B.O.D. removal and the B.O.D. loading is shown in Figure 7. The B.O.D. loading is expressed in pounds of 5-day B.O.D. per day per 1,000 lb. of suspended solids in the mixed liquor per hour of aeration. The performance at several military and municipal sewage treatment plants (8) is also shown in Figure 7 for comparative purposes. There is not a great deal of difference between the above-mentioned load relationships with aerating periods of 2 and 6 hr. and the performance at municipal plants. Aeration periods of 0.25, 0.5 and 1 hr. gave a different pattern of results. With these shorter aerating periods the percentage removal of 5-day B.O.D. was less than for 2 and 6 hr. of aeration with the same B.O.D. loading per 1,000 p.p.m. of suspended solids in the mixed liquor per hour of aeration. The foregoing tests indicate that a smaller percentage of B.O.D. removal is obtained per unit of aerating time and per unit of suspended solids in the mixed liquor for short aeration periods of about 1 hr. and less than for longer periods.

The relation between the percentage removal of B.O.D. from sewage and the percentage removal of suspended

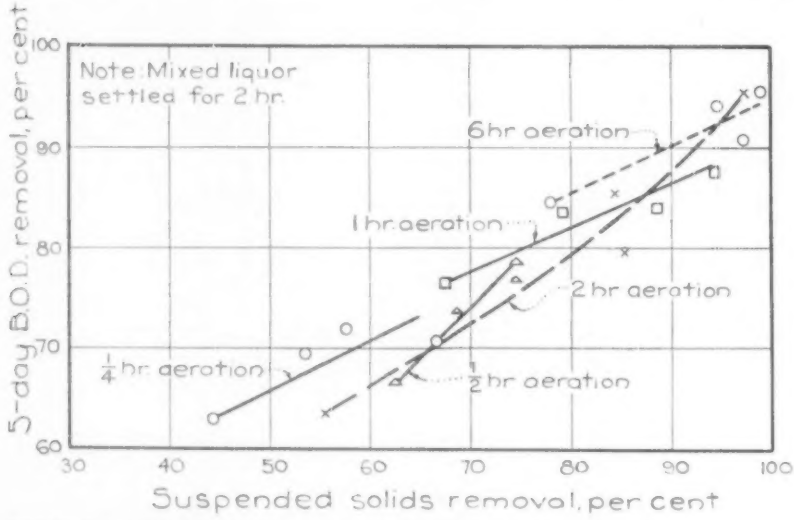

FIGURE 8.—Relationship between B.O.D. removal and suspended solids removal for various aeration periods.

solids after various periods of aeration is given in Figure 8. In general, the percentage removal of B.O.D. and of suspended solids increased as the period of aeration was increased.

In order to indicate how a single group of tests may vary from the average of a number of groups, the results in Table III and Figure 9 are given. In this case, the 5-day B.O.D.

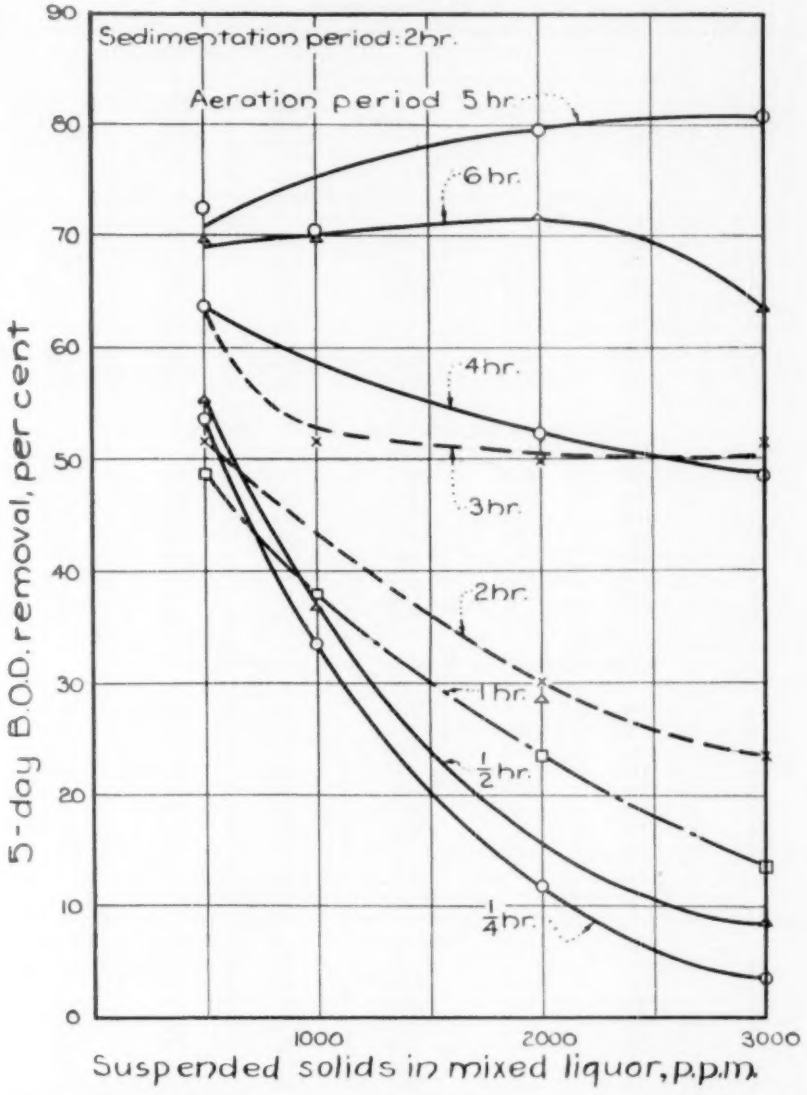

FIGURE 9.—Effect of aeration period and suspended solids in mixed liquor on B.O.D. removal.

removals were much less than those contained in Table II and Figure 5. With a ¼-hr. aeration period there was a wide variation in the removal, depending on the concentration of suspended solids in the mixed liquor. When the concentration was 500 p.p.m., the removal was 53.5 per cent;

TABLE III.—Effect of Aeration Period and Suspended Solids in the Mixed Liquor on the Removal of B.O.D. from Sewage

Aeration Period (hr.)	5-Day B.O.D.			*E*h Potential[1]		
	Untreated Sewage (p.p.m.)	Treated Sewage (p.p.m.)	Removal (%)	Activated Sludge Before Aeration (m.v.)	Mixed Liquor After Aeration (m.v.)	Act. Sludge After Aeration and 2-hr. Settling (m.v.)
(*a*) Suspended Solids in Mixed Liquor: 500 p.p.m.						
¼	120	55.8	53.5	138	333	350
½	120	53.8	55.1	166	360	378
1	120	61.8	48.6	136	378	365
2	120	57.8	51.8	217	370	382
3	120	43.6	63.6	238	368	383
4	120	43.3	63.9	155	370	393
5	176	48.8	72.4	144	393	396
6	176	54.0	69.4	123	397	391
(*b*) Suspended Solids in Mixed Liquor: 1,000 p.p.m.						
¼	120	79.8	33.5	103	342	321
½	120	75.8	36.8	146	366	316
1	120	73.8	37.7	98	390	342
2	120	57.8	51.8	158	388	357
3	120	57.5	52.0	225	385	379
4	120	57.5	52.0	115	387	389
5	176	52.2	70.4	99	406	396
6	176	53.2	69.8	99	401	399
(*c*) Suspended Solids in Mixed Liquor: 2,000 p.p.m.						
¼	120	105.8	11.8	82	372	190
½	120	95.8	28.5	111	396	275
1	120	91.8	23.5	72	395	286
2	120	83.8	30.2	134	394	320
3	120	57.0	52.4	198	403	363
4	120	60.0	50.0	99	392	378
5	176	35.5	79.8	79	427	351
6	176	50.0	71.6	89	416	394
(*d*) Suspended Solids in Mixed Liquor: 3,000 p.p.m.						
¼	120	115.8	3.5	82	272	178
½	120	109.8	8.5	91	379	221
1	120	103.8	13.5	58	375	220
2	120	91.8	23.5	107	379	238
3	120	61.7	48.6	178	392	347
4	120	58.0	51.6	85	398	356
5	176	33.5	81.0	65	425	281
6	176	64.0	63.7	70	423	319

[1] All values positive.

when the concentration was 3,000 p.p.m., the removal was 3.5 per cent. This differential between the maximum and the minimum removal became less as the aeration period was increased. In every instance, except for the 5-hr. aeration period, the B.O.D. removal became less as the suspended solids concentration in the mixed liquor increased. An aeration period of 5 hr. gave a slightly higher B.O.D. removal than a 6-hr. period. This apparent inconsistency in the results is somewhat difficult to explain. It should be noted, however, that the E_h of the mixed liquor was generally somewhat higher for the 5-hr. aeration period than for the 6-hr. period.

The E_h values of the mixed liquor at the end of the aeration period and of the activated sludge at the end of the 2-hr. settling period are given in Table III. In the case of mixed liquors that contained 500 p.p.m. of suspended solids, the E_h values of the mixed liquor averaged 370 mv.; after 2-hr. settling the sludge averaged 380 mv., an increase of 10 mv. In those instances where the suspended solids content in the mixed liquor was maintained at 1,000, 2,000, and 3,000 p.p.m., the E_h of the sludge after 2-hr. settling was less than at the beginning of the settling period, this difference becoming greater as the suspended solids concentration increased. This relationship between the E_h values before and after the 2-hr. settling period and the suspended solid concentration in the mixed liquor is shown by Curve A, Figure 10. This figure indicates that maintaining a high suspended solids concentration in the mixed liquor results in a greater decrease in the E_h

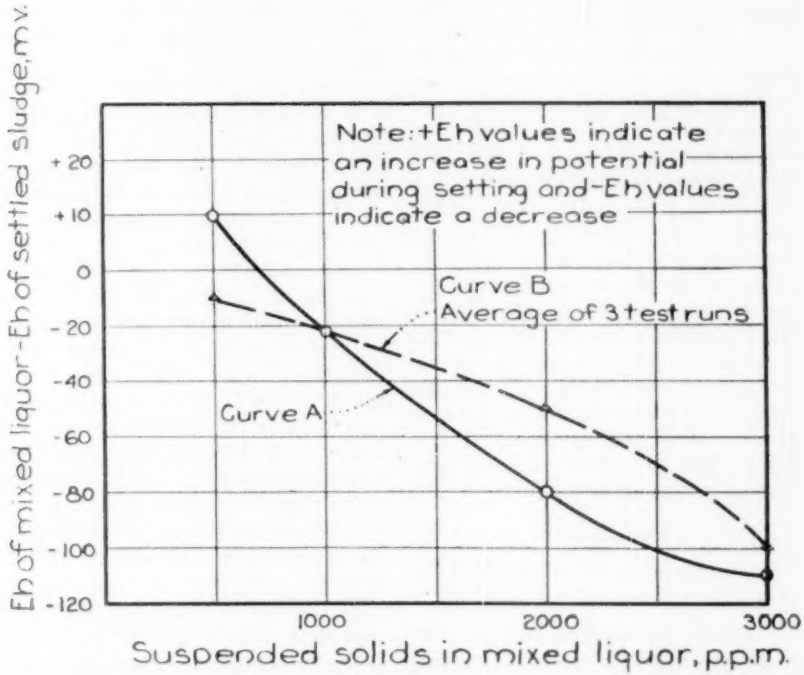

FIGURE 10.—Relationship between suspended solids in mixed liquor and difference in E_h of mixed liquor at end of aeration period and of sludge after 2-hr. settling.

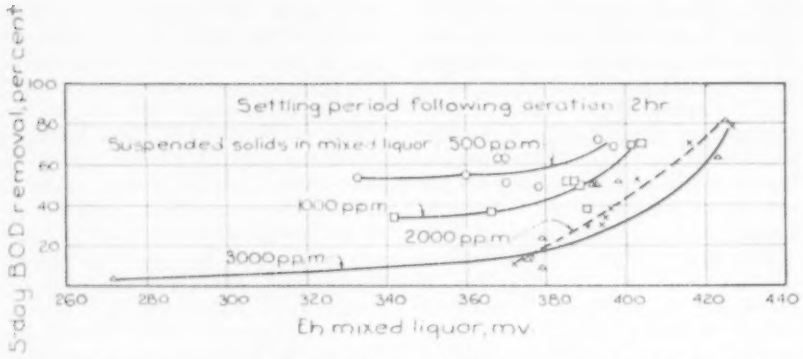

FIGURE 11.—Relationship between B.O.D. reduction in sewage and E_h of mixed liquor after aeration.

of the settled sludge. Consequently, when this sludge is again introduced into the aerating system, additional time and oxygen are required to raise the E_h of the sludge to a value to give optimum results. Figure 10 also contains Curve B, which is the average plot of three independent sets of results.

Figure 11 shows the relationship between the 5-day B.O.D. removed from sewage and the E_h value of the mixed liquor when maintaining various concentrations of suspended solids in the mixed liquor. These results indicate the necessity of maintaining a high E_h value in the mixed liquor, when the concentration of suspended solids is high, to obtain a given B.O.D. removal. For example, the B.O.D. removal was 60 per cent when the E_h value of the mixed liquor was 383 mv. with a suspended solids concentration of 500 p.p.m.; 420 mv. when the solids concentration was 3,000 p.p.m.

Conclusions

The following conclusions have been drawn from the experiments:

1. Fresh activated sludge in good condition, when mixed with sewage, was capable of removing without subsequent aeration a considerable percentage of the B.O.D. As the concentration of suspended solids in the mixed liquor was increased above 500 p.p.m., the ability of the sludge to remove B.O.D. decreased. The percentage of B.O.D. removed varied with the sludge used and depended on certain characteristics that are as yet unknown.

2. Preaerating activated sludge enhances its capacity in removing B.O.D. from sewage. The greatest removal was obtained when the concentration of suspended solids in the mixed liquor was 500 p.p.m.

3. No suitable mathematical expression for the removal of B.O.D. from sewage, when based on the amount of suspended solids in the mixed liquor and the aeration period, was formulated. Other factors, such as the types and number of bacteria present, together with their enzymatic secretions, are believed to play such an important role in B.O.D. removal that these factors must be considered when studying the performance of the activated sludge process.

4. There is an indication that maintaining a high concentration of suspended solids in the mixed liquor will, under certain conditions, result in a lowering of the B.O.D. removal. Such

reductions are less marked with longer aeration periods.

5. As the concentration of suspended solids in the mixed liquor was increased, the difference in the E_h of the mixed liquor at the end of the aeration period and the E_h of the sludge at the end of a 2-hr. settling period became greater. Because it is desirable to keep this difference as small as possible, the reason for maintaining a low concentration of suspended solids in the mixed liquor is more cogent.

Acknowledgments

The Back River sewage treatment works, where the above-mentioned experiments were conducted, is under the general supervision of P. L. Holland, director, Department of Public Works, with John J. Hunt, sewerage engineer. Dr. Abel Wolman is consultant to the Department of Public Works. R. T. Trautman, principal associate engineer, has direct supervision of the sewage works; Paul L. Smith is plant superintendent.

References

1. Keefer, C. E., and Meisel, J., "Activated Sludge Studies. I. Effect of Age of Activated Sludge on Its Oxidizing Capacity." THIS JOURNAL, **22**, 9, 1117 (Sept., 1950).
2. Baker, G. C., "Some Factors in the Purification of Sewage by the Activated Sludge Process." Bull. No. 16, Illinois State Water Survey, p. 182 (1918–19).
3. Henkelekian, H., "II. Factors Influencing the Clarification of Sewage by Activated Sludge." *Sewage Works Jour.*, **9**, 3, 431 (May, 1937).
4. Pearse, L., *et al.*, "The Operation and Control of Activated Sludge Sewage Treatment Works." *Sewage Works Jour.*, **14**, 1, 3 (Jan., 1942).
5. Greeley, S. A., "High Rate Biological Sewage Treatment." *Sewage Works Jour.*, **15**, 6, 1062 (Nov., 1943).
6. Mann, U. T., "Plain Aeration of Sewage." *Sewage Works Jour.*, **18**, 3, 459 (May, 1946).
7. Setter, L. R., "Plain Aeration of Sewage —A Discussion." *Sewage Works Jour.*, **18**, 3, 471 (May, 1946).
8. Fair, G. M., *et al.*, "Sewage Treatment at Military Installations—Summary and Conclusions." *Sewage Works Jour.*, **20**, 1, 52 (Jan., 1948).
9. Stanley, W. E., and Berberich, J. F., "B.O.D. Loadings in Activated Sludge Plants." *Jour.*, Boston Soc. Civil Eng., **35**, 3, 236 (1948).
10. Stanley, W. E., "Factors Affecting the Efficiency of Activated Sludge Plants." *Sewage Works Jour.*, **21**, 4, 625 (July, 1949).

SANITATION DISTRICTS IN KENTUCKY *

By H. A. Seaman

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A significant part of the local pollution load of the Ohio River originates in the Kentucky communities facing Cincinnati, Ohio, on the south. Sewage outfalling from these communities, presently discharging for the most part in a raw state, finds its way into the Ohio and Licking Rivers. The percentages of the load comprising domestic and industrial waste categories are similar to those originating on the Ohio side of the river, there being a large industrial development in the Kentucky communities, a part of whose wastes are both complex and highly concentrated. Common frontage on the river and identical uses of the stream have given rise to similar interests in pollution control on both sides of the river.

The number of municipal corporations in the area of Kentucky contiguous to Cincinnati causes the pollution abatement problem to become involved. The principal urban development occurs in two counties, which are separated by the Licking River. Population, business, and industrial development are about equally divided between the two counties. In all, some 20 municipal corporations are found within the area; the majority of these have common boundaries with one or more of the others. Some have no frontage along the receiving watercourses and their wastes pass through adjacent communities before outfalling into the Ohio or Licking Rivers.

Joint Action Facilitated

Topographically, the municipalities occupy the Ohio and Licking River flood plain and the adjacent sloping valley walls. Sixteen of them, containing about 90 per cent of the population of the two counties, are so situated in a common local drainage basin as to offer attractive features for joint action on their waste disposal program. Existing sewer systems are well developed for the area within this group of communities and outfalls are concentrated along the Ohio and Licking Rivers. Construction of collector lines to service these outfalls is facilitated by unencumbered right-of-way for alignment and grades, which require neither deep excavation nor excessive pumping. In a joint action, it is possible to deliver the waste for treatment to a point on the Ohio downstream of any local urban development on the Kentucky side of the river. It was also recognized, in view of the concentrated grouping of these communities, that the job of waste treatment could be done better and probably at cheaper cost at one location than to have attempted it at each community. Fortunately, local rivalry did not arise to stand in the way of joint action and means were at hand in the form of a recently passed Kentucky law which permitted and encouraged the municipalities to get together on their common problem. Without the facilities offered by Kentucky Revised Statutes 220, it appears doubtful that the Northern Kentucky communities could have achieved their present rapid progress in preparing for waste treatment. Their difficulties have been largely political and financial in overcoming the physical handicaps to be found in individual action.

* Presented at 1950 Annual Meeting, Ohio Sewage and Industrial Wastes Treatment Conference; Cincinnati, Ohio; June 28-30, 1950.

Statute Provisions

The Kentucky statute covers three main points of interest in respect to the present development. It provides, with adequate safeguards against abuse, for quickly establishing a sanitation district, for constructing and operating sewage collection and treatment facilities, and for financial responsibility in carrying out these operations. Upon petition of the governing body of any municipality, or upon petition of 90 per cent of the freeholders of an area, and following investigation by the Commissioner of Sanitation Districts, a sanitation district can become a political entity. Its boundaries are those established in the petition or as modified by action of the Commissioner of Sanitation Districts. Appointment of commissioners for the particular sanitation district is immediately mandatory upon the County Fiscal Court and the district becomes operative upon their appointment. The powers granted the commissioners with respect to the extent and type of sewage treatment systems is broadly discretionary. Similar discretionary powers are granted with respect to financing the operations of the district with, if required, the district's obligations having a first lien on the property taxes within the district.

District in Cincinnati Area

The municipalities of Campbell and Kenton Counties are the second sanitation district to make use of the Kentucky law. In December, 1946, the municipalities of Fort Thomas, Dayton, Bellevue, Newport, Wilders, Southgate, Covington, Ludlow, Bromley, Park Hills, Lookout Heights, Woodlawn, Winston Park, Forest Hills, South Hills and Kenton Hills petitioned for and were subsequently organized into a unit designated as Sanitation District Number One of Campbell and Kenton Counties, Kentucky. The boundaries of the District encompass the above cities, as well as some adjacent unincorporated area, and will serve about 145,000 persons of the 165,000 living in the two counties. Principally, all industries found within the counties are within the District boundaries.

The purposes of the District are stated to be the abatement of pollution from sanitary and industrial wastes originating in the District. Although its formation shortly antedates the Ohio River Compact, it appears to be a well-suited means for carrying out the provisions of the Compact in its territory. The Sanitation District has prepared and had approved by the Kentucky State Health Department a preliminary plan for collector sewers, appurtenant works, and treatment plant. Construction plans and specifications for units following this plan are well advanced; construction is scheduled to start in the spring of 1951. Financing for construction funds is being negotiated and has reached a stage where no difficulties in completing the arrangements can be foreseen. It is anticipated that treatment of wastes now entering the Ohio River, and having a population equivalent to 210,000, will be commenced late in 1952. The degree of treatment will be such as to create an effluent meeting the Ohio River Compact Commission's regulations for the Cincinnati pool.

Future expansion, both as to enlarging the area within the District and for growth within the existing District, is being provided for. Similarly, the possibility of a greater degree of treatment being required in the future has been recognized. Collector mains are designed to permit extension to areas now draining toward but outside of the District limits. Based on population trend studies for the area, the mains will be built to serve a predicted population of 175,000. Pump installations and treatment plant facilities are based on 1960 populations. Sufficient area has been acquired at the plant site to

accommodate complete treatment for the predicted future population.

The Northern Kentucky Sanitation District will limit itself to construction and operation of collector mains and treatment facilities, leaving to the various municipalities the maintenance, repair, and extension of the sewer systems now found in the incorporated areas. As a result of this decision the District is unable to assess and collect sewer rental charges in advance of completion of its facilities. This fact has somewhat slowed the start of actual construction by making it necessary to complete plans and take bids at one time on all units involved in the District plan. The advantages of allowing the existing municipal sewer systems to remain the responsibility of the particular municipalities was felt to outweigh the loss of an estimated six months in completing the treatment facilities.

The District, however, has retained a regulatory authority with respect to surface dumping of untreated wastes within the municipalities and will require that any such wastes be conveyed to its collector system. It has also retained authority with respect to types of industrial wastes it will accept for treatment and the authority for establishing means of disposal of those wastes unacceptable in their original state. The problems which will arise from these categories of waste have yet to be met and solved, but they have been foreseen and considered. A survey of industrial wastes revealed a normal number of grossly polluting loads, but most of these are of a nature which can be readily dealt with. In only three instances were the wastes complex or excessively costly to neutralize.

Sewer Rentals

Sewer rental charges based on amount of water used and strength of waste will provide revenues for the District. Public water supplies are furnished by both public and private companies, there being four such operating in the District with these having different rates in different communities. It has been necessary to schedule a flat rate for sewer rentals applicable to all users within the District. The question of collection and enforcement of the sewer rental charges is also rendered complex by this situation.

On the other hand, almost 100 per cent of water used is metered to the individual consumer and when the method of rental collection is worked out, an equitable distribution of treatment costs can be made. A significant amount of the industrial water supply is derived from wells and direct from the Ohio or Licking Rivers. A field survey of this situation revealed acceptable facilities available for accounting for the amount of water thus used, and in general, a cooperative attitude on the part of such users. A large amount of water, derived from the river, is now used by a few of the industries for cooling purposes and is uncontaminated except for mixing with other effluents from the plant. Negotiations are in progress with these users to encourage them to separate their systems, returning the uncontaminated water direct to the river and sending only polluted water to the sewer system.

As previously indicated, right-of-way for collector mains is readily obtained without interfering with existing development. Much of the frontage along both the Ohio and Licking Rivers has remained undeveloped due to the flood hazard. The open area offers attractive collector locations, due both to their proximity to the outfall ends of existing sewers and because the sloping river bank permits establishing desired sewer gradients with a shallow depth of trenching. In places of exception to this general picture, city streets are available for sewer location, but at the expense of considerably deeper sewer excavation.

The river bank, where used for col-

lector alignment, is of gentle slope averaging about 1 on 4. For the most part, the bank is on the concave side of the river and is either stable or subject to accretion during flood periods. The sewer gradients are further dictated by assuring the collector system will continue to function up to an Ohio River stage of 40 ft. gage (elevation 470) and the prospect that the Cincinnati navigation pool will be raised in the future to an elevation of 463.

Construction of about 24 mi. of collector mains ranging in size from 12 to 72 in. will be required to serve the District. Two inverted siphon crossings of the Licking River and several sections of aerial sewer are included in the system. The main collector is approximately T-shaped with the vertical leg extending up the Licking River and the horizontal leg extending along the Ohio River. Four lift stations are included in the system; that at the treatment works has a capacity of 23,000 g.p.m.

The treatment plant is to be located on the Ohio River west of Bromley. The present installation will give primary treatment to the influent during periods of normal flood in the Ohio River. During periods of low flow of the River the process will be supplemented by chemical precipitation. At and above a 40-ft. stage of the River the plant will go out of operation. Raw sludge will be filtered and incinerated.

HERRIN, ILL., BUYS HOUSEHOLD GARBAGE DISPOSERS

Garbage collection difficulties at Herrin, Ill., are being overcome by municipal purchasing of household garbage disposers for resale to householders. Mass purchasing, accomplished through the community's water department, makes a substantial savings in individual installations.

The plan is the result of high garbage collection costs and unsatisfactory service, coupled with a desire to make maximum use of the city's new $300,000 sewage disposal plant. Widespread installation of garbage disposers in new houses being built by contractors was cited by city officials as a selling point for the program, which is adapted from that followed previously at Jasper, Ind. [see THIS JOURNAL, **22**, 3, 288 (Mar., 1950); also, **22**, 3, 1138 (Sept., 1950)].

Installation of the appliances is being handled by local electrical and plumbing contractors. Financing is on either a cash or a time-payment basis by the city, but underwritten by a local bank.

SEWAGE SERVICE CHARGE PRACTICE*

By Myron W. Tatlock

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The importance of the use of rates and a rate schedule for financing construction, operation, and maintenance of sewage systems is evidenced by the fact that at least 273 cities of more than 10,000 population have adopted the use of sewage rental charges and dropped expenditures for sewage disposal from their general tax budgets, and that rental collections totaled more than $25,000,000 during 1948 from the approximately 450 cities now using the plan.

Camden, N. J., was the largest city to adopt these charges in 1949; the rate schedule there brought in more than $227,000, although it was not in effect for the entire year. Lansing, Mich.; Portsmouth, Va.; Joliet, Ill.; Mason City, Iowa; Morristown, Pa.; and Wichita Falls, Tex., were some of the other cities adopting the plan during the year. Cleveland, Detroit, and Philadelphia, each having a population of over 500,000, use the charge to finance their disposal operations, and New York City has just recently adopted the plan. The only large city which has considered and rejected the plan is Los Angeles, where the plan had the approval of the mayor, the Board of Public Works, and the Council's Finance Committee prior to its rejection by the City Council. The proposed rate schedule would have raised almost $6,000,000 annually based on the charges ranging from 16.5¢ monthly for hotel rooms to $116.25 for commercial and industrial customers, depending on water meter size.

Adoption of a sewage service charge by New York, the country's largest city, commands more than ordinary interest because it should accelerate a trend toward service charging which will have a marked effect on municipal financing and sanitation progress. The mayor pointed out to the City Council that the city's vast sewage disposal plan would have to be postponed if additional funds were not found from some source outside the city's strained and tax-limited debt structure. He also pointed to the fact that adoption of the plan would permit the city to exclude a major portion of its sewage treatment construction costs from its bonding limits and permit it to use such funds for other improvements; would put sewage treatment on a self-sustaining basis; would cancel city-wide assessments for sewage treatment plants; and service existing sewer debts. The plan passed with only one dissenting vote.

The ordinance establishes a rate of about one-third of the existing water rate, or about 40¢ per residence per month. It also levies charges against commercial and industrial users, and exempts users who do not now have any direct share in the cost of sewage service other than real estate taxes. It is expected that the rate schedule will produce an annual revenue of approximately $15,000,000. A casual examination indicates that the plan apparently was not designed to charge total annual expense to both property and persons, that it was adopted because it would be relatively painless to

* Presented at 23rd Annual Meeting, Federation of Sewage and Industrial Wastes Associations; Washington, D. C.; Oct. 9–12, 1950.

the consumer and inexpensive to administer, permitting the city to tap a source of revenue outside the statutory debt limitations.

Assisting Legislation

Present practices are not static because of changes being made in the statutes upon which they are based. The latest wave of new legislation is the result of emphasis on water pollution control programs, which have established boards with authority to order pollution abatement—but with no answer to the question of where a municipality may get the money to construct the improvements when it has no debt margin under statutory debt legislation.

Ohio has legislation creating a Water Pollution Control Board with authority to issue orders, but with no answer to the financing problems within statutory debt limitations. This means that such remedial measures must be financed by means of revenue bonds retired by funds accumulated through the establishment of a rate schedule for the collection of a sewage rental charge. Such bonds are not better than their "sales appeal" based on a guaranteed income. There is considerable evidence that present high construction costs will require such a high service rate from the sewer users that the required income cannot be guaranteed, and the required sales appeal is lacking. The statutory authority to shut off water service because of failure to pay a sewage service charge, or to certify the delinquent account as a lien against the property, is not sufficient to make the bonds an attractive investment.

A Georgia law permitting a city to unify municipally owned water and sewage utilities under one financial structure, and to pledge a portion of the revenue from both utilities for the retirement of revenue bonds for the expansion of either utility, should add sales appeal to this type of bonds. The fact that the state Supreme Court has held that water rates may be raised to supply money for the construction of sewage works, whether there is a sewage rental charge or not, and that a water user's rate may be raised for this purpose whether or not the water user is served with a sewer connection, should make them still more attractive.

New York State recently took action which should promote the attractiveness of this type of bond when the 1950 legislature amended the state constitution to permit municipalities to exempt from their debt limitations up to 75 per cent of the cost of constructing sewage systems, if they can show in the blueprint stage that they are self-sustaining through the use of sewage rentals or similar devices. This act will make it possible for more than 100 cities, villages, and towns to construct treatment works, leaving only 25 municipalities financially unable to proceed with such improvements.

Although sewage service charges are used by so many cities and their use is becoming more universal, there are 13 states which do not have legislation permitting revenue bond financing for sewer construction and 11 states which do not have enabling legislation allowing sewer districts.

Need for Sewage Service Charges

Sewers have been used for many years. However, the installation of sewage treatment works is a relatively new municipal business, which has grown up since the usual sources of municipal revenues have all been appropriated for other uses, statutory debt limits have been reached or property will not carry additional tax burdens. This has resulted in a search for additional revenues and an interest in special charges for the use of sewage systems (commonly referred to as "sewer rentals," "sewer service charges," or more correctly named "sewage service charges") based on some sort of rate schedule, and the

adoption of such charges has become a source of badly needed income. Because municipalities generally are not required to secure the approval of their rate structures by utility commissions or other state bodies, they are usually free to raise as much or as little revenue as they choose, subject, of course, to statutory limitations, or the ability to find a market for the bonds.

The most important problem in the field of government is the proper distribution of the cost of governmental operations among the various members of the community. The establishment of a sewage service rate schedule necessarily presents the question of how much revenue should be raised and what portion of sewage service cost should be borne by service charges, and what portion by general taxation.

An examination of current practices indicates that municipalities charging sewage rentals show wide variations in the extent to which such revenues are relied upon to meet the cost of sewage services. Some use such charges to finance the construction of new sewer systems or new treatment plants, others to pay the debts on existing sewage works, and still others to pay only current operating and maintenance costs of the sewers or treatment plant or both. The wide range in the amount of funds raised by this method and the bases for the collection of such funds make it appear that few rate structures have been scientifically designed, but that they are the result of a plan to raise some definite amount of revenue in the least painful manner, rather than to fix the charges in true relation to the cost of providing service. Although the collection of sewage service charges transfers some of the burdens of government from one group to another, it appears that few rate schedules should be considered as a source of a portion of the entire revenue system of the local government.

Existing Rate Structures

The following information is based on the answers to two questionnaires prepared and mailed to municipalities by the American Public Works Association. The first questionnaire, mailed in 1939, brought 116 answers; the second mailed late in 1949 to 456 municipalities of over 5,000 population, has brought answers from more than 50 per cent of the cities.

These studies disclose the use of six principal bases in fixing rate schedules for sewage service charges; but practically everything excepting the color of plumbing fixtures has been used some place as the basis for such charges. The principal bases may be classified in the following broad categories. The order of reporting is not intended to indicate any preference for their use.

Uniform Rate

Uniform rates for all properties seem to have been the simplest and easiest to establish. Although they propose to spread the cost uniformly among all users, the charges seem to have been determined by setting any rate sufficient to produce the required amount of revenue. Therefore, they do not represent either the amount to be paid for the actual or the presumptive use of the sewage facilities. The result is inequitable charges; that is, a commercial laundry may pay no more than a private residence. Simplicity is the only recommendation for this type of rate schedule. Its use is restricted to small communities, and the annual rates vary from $3.00 to $10.00.

Number and Type of Sewer Connections

This type of rate, similar to the uniform rate, is based on the fact that a property with more than one sewer connection offers presumptive evidence of greater use of the sewers. Different rates may also be charged for different size sewers, and a two-family building may be charged more than a single

residence, even though there is only one sewer connection. This type of schedule is also restricted to use in small communities where important differences among properties do not exist to any great extent. The rates for a single connection may vary from $15.00 to over $25.00 per year.

Type of Property

Charges have been based on different types of property, on the assumption that the use of a sewage system depends on the size of a residence or the size and kind of a commercial or industrial plant. Although some cities use but seven or eight property classifications, others use forty or fifty, which serve to eliminate many inequalities that would otherwise exist. Maximum charges for the various property classifications vary from $12.00 for a residence or railway depot to $60.00 for a garage.

Number and Type of Plumbing Fixtures

The number of plumbing fixtures as the basis for rate structures has found favor where the waterworks is privately owned, where water meters are not installed, or where it seems desirable to favor the poorer classes of users. This base roughly measures the use of sewers, but its administration requires frequent and costly inspections of plumbing installations to assure complete and accurate billing. Additional units of any kind are usually charged at a lesser rate and rates for the different types of fixtures range from $0.20 for a hotel bathtub, to $0.30 for a public garage wash rack.

Water Consumption

Water consumption represents the most accurate measure of the relative use of a sewage system. In general, it results in the most equitable distribution of charges. Its use, however, is limited to an entirely metered service, or to a municipally owned system, unless arrangements can be made with the private water company to make its meter readings available to the municipality.

This type of rate structure is divided into the following subclassifications:

1. Metered water charges.—A sewage service charge based on metered water consumption represents the most accurate measure of the relative use of the sewage system and, in general, results in the most equitable distribution of charges. However, inaccuracies and inequalities are introduced when all the water used is not discharged into the sanitary sewer system. On the other hand, the plan is faulty in that it does not take into account the benefits to vacant property because of the availability of sewage facilities, and to large commercial and industrial users that use very little water. The plan requires adjustments for both users and properties if each is to contribute in proportion to the benefit derived.

Rate schedules of this type usually include a minimum charge, which is found to vary from approximately $1.00 to $9.00. The rates, usually on a sliding scale basis, with a lower charge for greater quantities of water, indicate maximum charges in the first block approximately 50 per cent more than the minimum; the lowest block charges are about two-thirds of the first block.

2. Combined sewage and water charges.—A combined sewage and water charge is not commonly used. Where the previous discussion of charges based on metered water implies a separate sewage charge, even though it was placed on the water bill, this plan provides for only one service charge to cover both water and sewage services. It, therefore, is not a sewage service charge. The plan has no advantage except simplification of bill-

ing procedure and extreme care would have to be taken in analyzing and comparing the rates if the charges are to reflect the cost of service rendered.

3. Charges based on metered water and B.O.D.—A charge based on metered water and the strength of the sewage is much more exact than just measuring the quantity of water or sewage, particularly if the charge covers sewage treatment. The charge should be based, therefore, on the type of treatment process and the proportion of the receipts used to pay treatment expense. Such a plan is not applied to all sewage sources, but only where it is suspected that the concentration is especially high or low, and then a special rate is often established.

4. A fixed percentage of the water bill.—Sewage service charges established as a fixed percentage of the water bills are perhaps the most numerous. The billing procedure is simpler and cheaper than when a separate rate structure is adopted. The plan includes all properties, whether the water service is metered or not. Such a plan would rarely distribute the cost of service equitably to the connected properties; it only tends to perpetuate any inequalities of the water rate schedules and assumes that the cost of providing the two types of service are in the same proportion.

Sewer billings show no fixed percentage of the water bills. The total range is from a minimum of 10 per cent to a maximum of 200 per cent, but these percentage figures have little meaning unless the water rate structure is also known.

Miscellaneous Methods

One or two cities reported rates based wholly on the size of the water meters used. The plan has the advantage of being very easy and inexpensive to administer, but at the best it gives only a very rough measure of the presumptive use of the sewage facilities.

One city, Phoenix, Ariz., reported a sewage service charge based on metered sewage services for out-of-city customers, who pay $0.70 per 1,000 gal. Such a plan probably most equitably measures the relative use of a sewage system, but sewage meters have not been developed which will accurately measure small quantities of sewage. It appears that the added cost of meters, meter reading, billing, and administration would add an excessive burden to property owners and users who now complain of too-high rates.

Summary of Plans

These plans vary quite widely and show great differences in the charges under each plan. It is evident that the rates do not reflect the efficiency of the service rendered, the extent and cost of operation, or the effectiveness of the sewage systems or treatment plants. The rates and total revenues vary so widely because they are used in so many different ways and to pay for different parts of the service. A few cities use sewage service charges to finance the entire sewage system; other cities plan to collect enough from such charges to pay operating and maintenance expense of the sewers and treatment plants; others only want sufficient funds to operate and maintain the treatment plant; and still others use such funds to pay only the debt service on the treatment plant. Therefore, if some rates seem excessively high and others extremely low in comparison, the answer likely lies in the use for which the rates were established.

A summary report shows the use of sewage service charges by 45 cities in Indiana, ranging from a minimum of 80 to a maximum of 33,000 customers. Of these cities, 78 per cent based the sewage service charge on water consumption, 11 per cent used a fixed charge basis, and 11 per cent based the charge on the number or type of con-

nection. Minimum annual charges ranged from $1.32 to $30.00 per customer.

There are other plans in successful use which reflect careful planning prior to their establishment and even special enabling legislation. The plan in use by the Washington Suburban Sanitary District is an excellent example. This plan, covering both water and sewage, operates under an enabling act giving the district wide powers, including the right to issue bonds without referendum, to levy taxes or special assessments, and to fix rates for utility services. The original act was designed to meet fixed charges on construction bonds by a low tax on all property in the district, plus a front-foot benefit charge on those properties abutting water and sewer lines, with maintenance and operating expenses to be covered by water consumption charges. Later amendments permitted the financing of construction costs of supply and purification works through water and sewage rates, supplementing tax funds. This was done to keep the general tax rate at a low level. As a result the tax rate was reduced from $0.07 to $0.06 per $100 of property valuation in 1946. This tax raised $126,000 in 1948 (approximately $0.50 per capita) or 5.7 per cent of the total annual revenue.

Front-foot benefit assessments are charged over the full term of the bonds (now 40 years), again resulting in low annual charges to the property owner. Property for assessment purposes is classified as (a) business, (b) subdivision, (c) small acreage, and (d) agricultural. The classification may be changed as the property use changes.

Front-Foot Benefit Charges

Types of Property	Water	Sewer
Business, first 200 ft.	$28.00	$30.00
over 200 ft.	$20.00	$22.00
Subdivision, first 150 ft.	$20.00	$22.00
over 150 ft.	$10.00	$11.00
Small acreage, first 150 ft.	$20.00	$22.00
next 150 ft.	$10.00	$11.00
over 300 ft.	$ 8.00	$ 6.00
Agricultural, if converted acreage, 150 ft.	$20.00	$22.00

Front-foot charges are 20¢ for water and 22¢ for sewers.

This type of charge produced an income of $1,081,000 during the year 1948 (approximately $4.30 per capita), or 45.5 per cent of the total annual revenue for that year.

Water consumption charges cover both water and sewage. They were raised in 1949 from 22¢ to 27¢ per 1,000 gal. An annual ready-to-serve charge, ranging from $2.00 for a ⅝-in. meter to $4.50 for a 10-in. meter, is also included in this source of income. This type of charge produced an income of $1,160,000 during the year 1948 (approximately $4.65 per capita), or 49.2 per cent of the total annual income for that year.

This type of financing has proven so satisfactory that it has been followed, entirely or partially, by other sanitary districts.

The plan for collecting sewage rates used by the Buffalo Sewer Authority is still different, but interesting. This Authority has adopted a two-part rate structure, which provides for the collection of 45 per cent of the required annual income as an ad valorem tax against property, and 55 per cent from water use rates. The rate structure also provides allowances for water not returned to the sewers, for water used for sprinkling, as well as special rates for wastes difficult to treat and for users outside the city. The income pays the charges on all capital expense, the cost of operation and maintenance of the sewers and treatment plant, and the establishment of a reserve fund.

This type of charge produced an income of $1,770,500 during the last fiscal year, or approximately $3.00 per capita. Property taxes produced $857,000 from tax rates of $0.92056 and $1.85 per $1,000 valuation, respec-

tively, for properties inside and outside the city limits; $913,000 was collected for water use, of which $462,000 was paid by 18,500 metered accounts and $451,000 was paid by 80,000 flat-rate accounts. No complaints have been registered in the 12 years the plan has been in operation.

There are no doubt many more interesting plans for the collection of sewage rental charges, but it is believed that those reported herein are representative of present practices.

Acknowledgment

Acknowledgment is made to the American Public Works Association for use of their questionnaire on this subject, and to all the associations and their representatives on the Joint Committee on Fundamental Considerations in Rates and Rate Structures for Water and Sewage Works, the writer having been privileged to be a participating member of the committee as a representative of the American Public Works Association.

SANITARY ENGINEERS AND SELECTIVE SERVICE

The selective service status of sanitary engineers is concisely clarified in a letter, dated November 8, 1950, replying to a resolution of the Federation Board of Control regarding the proper allocation of sanitary engineering services to their best use during national emergencies. The letter, written by Colonel Joel D. Griffing, Chief, Manpower Division, Selective Service System, Washington, D. C., reads in part as follows:

"Selective Service Regulations provide local boards with ample authority to defer a sanitary engineer whose employment is found to be necessary to the maintenance of the national health, safety, or interest.

"The Selective Service Act of 1948, as amended, prohibits deferments by groups or categories and requires that each deferment granted must be given on the basis of the individual status of each registrant. Responsibility for the classification of registrants lies initially with the local board. Rules and regulations as prescribed by the President and under which local boards operate are broad. They are not complicated nor do they confuse the issue by attempting to spell out the case of any person or group of persons.

"Any employer of civilian manpower may present to the local board in detail all he may wish to offer in support of any request for deferment of any individual liable under the Act. The employer may present his request in writing in any manner he deems appropriate inasmuch as no special form is provided or required in this instance. If a request for occupational deferment is denied by the local board, the registrant or his employer, if he filed a request for deferment prior to the classification from which he desires to appeal, has the right to appeal as set forth in the Selective Service Regulations. If the appeal board upholds the classification given by the local board, but, if in doing so, one or more members of the appeal board dissent, then the appellant has recourse to the National Selective Service Appeal Board which has adequate power to act in all cases coming before it.

"It is to be observed from the information outlined above, that either the registrant or his employer may request occupational deferment and in support of such request they are at liberty to set forth any information which they believe should be considered as indicating that the registrant's activity in the above-mentioned employment is necessary to the maintenance of the national health, safety, or interest.

"It is suggested that in all cases complete information should be provided to a registrant's local board and it should normally be filed with the registrant's questionnaire or at least anticipate the classification action of the local board. This is necessary to vest in the employer his right of appeal.

"The individual assignment of a member of the armed forces is a matter within the jurisdiction of the Department of Defense."

Industrial Wastes

COLORIMETRIC DETERMINATION OF METALS IN SEWAGE AND INDUSTRIAL WASTES

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Discharge of metallic wastes from electroplating plants and other metal-processing industries has become a matter of serious concern to public health authorities in many areas. Investigations of the various problems associated with stream pollution by metals (such as the effect on fish life, sewage digestion, and potability) have generally been handicapped by a lack of suitable analytical methods for the heavy metals involved. Most methods now recommended for water analysis are subject to serious interference by even moderate concentrations of other cations and anions, and it is not unusual to find several heavy metals present in a single sample of polluted water.

To overcome this difficulty, a program was undertaken for development of methods for cadmium, chromium, copper, iron, lead, manganese, nickel, and zinc in sewage and industrial wastes. This paper presents colorimetric methods for each of the above metals; the methods are designed to allow the determination of as little as 0.05 mg. (0.05 p.p.m.) of the ion in question in a 1-l. sample, and are applicable in the presence of the other heavy metals listed up to at least 200 times the concentration of the desired constituent. Allowance is also made for the presence of organic matter and such anions as may commonly be found in polluted water. Detailed procedures are given for preliminary treatment of the sample, qualitative identification of the heavy metals present, and quantitative analysis by photoelectric colorimetry.

PRELIMINARY TREATMENT OF SAMPLES

Samples of polluted water or sewage are evaporated and digested with acid to destroy organic matter. The procedure to be followed depends on the organic content. Digestion with a mixture of nitric and sulfuric acids serves for most samples; but when the organic matter is difficult to oxidize, perchloric acid is substituted for sulfuric acid. Perchloric acid digestion is also recommended when lead is to be determined. A special perchloric acid procedure is included for samples of unusually high organic content, such as sewage concentrates.

The amount of sample to be evaporated depends on the concentration of the metals to be determined. A 1-l. sample should be taken if analyses are to be made for any constituents present in less than 1 p.p.m. concentration.

1. Apparatus

1.1. Evaporating dishes, 500-ml. capacity. Procelain or vitreosil may be used.

1.2. Filtering flask.

1.3. Sintered glass crucibles or porcelain filter crucible and holder.

2. Reagents

2.1. Nitric acid, concd. Reagent grade.

2.2. Sulfuric acid, concd. Reagent grade.

2.3. Perchloric acid, 60 per cent. Reagent grade.

2.4. Ammonium acetate solution, 40 per cent. Dissolve 400 g. of $NH_4C_2H_3O_2$ in 600 ml. of water. This solution is required only if lead is to be determined in the presence of sulfate.

3. Procedure

3.1. Digestion with nitric and sulfuric acids. Agitate the sample to obtain a homogeneous suspension of solids, measure out a suitable volume by means of a volumetric flask, and transfer to an evaporating dish. Acidify the sample with 5 ml. of HNO_3 and evaporate on a steam bath to 15 to 20 ml. An infra-red lamp placed over the sample hastens the evaporation. Transfer the solution, together with any solids remaining in the dish, to a 125-ml. conical flask; add 5 ml. additional HNO_3 and 10 ml. of H_2SO_4, and a few glass beads or carborundum chips to prevent bumping. Evaporate on a hotplate until dense white fumes of SO_3 appear in the flask, but do not continue heating beyond this point. If the solution is not clear, add 10 ml. additional HNO_3, and repeat the evaporation to SO_3 fumes. Cool the solution to room temperature and carefully dilute to about 50 ml. Filter through a sintered glass filter or porcelain filter crucible and wash the residue with two small portions of water. Then transfer the filtrate to a 100-ml. volumetric flask, dilute to volume with water, and mix. The resulting solution is about 3 N in acid. Aliquots of this solution are taken for the determination of metals.

If the sample contains lead, $PbSO_4$ will be present in the residue on the filter. In such a case, add 50 ml. of hot 40 per cent ammonium acetate to the conical flask in which the evaporation was carried out, and then draw this solution through the filter in order to dissolve the lead salts. Cool the filtrate, transfer to a 100-ml. volumetric flask, dilute to volume, mix, and set aside for the determination of lead.

3.2. Digestion with nitric and perchloric acids. The procedure is similar to that given for H_2SO_4-HNO_3 digestion, except that 10 ml. of 60 per cent $HClO_4$ is substituted for H_2SO_4. After evaporating to dense fumes of $HClO_4$, the solution is diluted to about 50 ml., boiled to expel chlorine, cooled, filtered, diluted to 100 ml., and mixed. The resulting solution is about 0.8 N in acid.

If the sample contains both lead and sulfate, treatment of the insoluble residue with ammonium acetate must be carried out as described in 3.1.

3.3. Digestion of sludges of high organic content. Evaporate the sample to small volume in a large evaporating dish, add 12 ml. of HNO_3, and evaporate to near dryness. After repeating the addition of HNO_3 and evaporation once more, transfer to a 250-ml. conical flask, add 25 ml. of 1:1 HNO_3 and 25 ml. of 60 per cent $HClO_4$ and boil until nearly dry. Take up in 50 ml. of water and proceed as in 3.2.

QUALITATIVE TESTS FOR METALS

It is important to have available a simple qualitative test for the presence of the various metals for which quantitative methods have been developed. Spot tests and microscopic tests are ideal for this purpose. Those selected are the most satisfactory from a standpoint of specificity, sensitivity, and simplicity. They may be applied to the sample as received, but it is preferable to test the more concentrated solution obtained by the preliminary treatment of the sample. This concentrated solution is free of organic material, which might interfere with the tests. It seemed desirable to express the sensitivity of the reactions in p.p.m. rather than in the conventional terms of "limit of identification" and "limiting concentration."

Cadmium

Method A. Spot Test with Ferrous 2,2'-Bipyridine Iodide Solution

About 1 p.p.m. cadmium can be detected in the presence of 10 p.p.m. each of Cr, Cu, Fe, Mn, Ni, Pb, and Zn.

1. Procedure

A drop of dilute HCl is added to the test solution and the solution is centrifuged to remove the precipitate of $PbCl_2$. The solution is made ammoniacal and centrifuged. A drop of the supernatant liquid is placed on No. 601 S and S test paper, and a drop of reagent is added before the test drop soaks into the paper. A red fleck indicates the presence of cadmium. When cadmium is present in very low concentrations, it may be necessary to compare the spot with one formed by the reagent alone.

2. Preparation of Reagent

2,2'-bipyridine (0.25 g.) and ferrous sulfate (0.146 g. $FeSO_4 \cdot 7H_2O$) or ferrous ammonium sulfate (0.20 g. $FeSO_4 \cdot (NH_4)_2SO_4 \cdot 6H_2O$) are dissolved in 50 ml. of water, 10 g. KI added, and, after shaking vigorously for 30 min., the $Fe(2,2'\text{-bipyridine})_3I_2$ is filtered off. The resulting saturated solution of the complex contains excess KI. If the reagent has been standing for some time, it may be necessary to filter before use [see Feigl, "Qualitative Analysis by Spot Tests," p. 74 (1946)].

Method B. Microscopic Test with Reinecke's Salt and Thiourea

A drop of a filtered 1 per cent aqueous solution of Reinecke's salt, $Cr(NH_3)_2(SCN)_4NH_4$, containing 2 per cent thiourea, drawn into a drop of a neutral or slightly acidic cadmium test solution on a microscopic slide, forms a precipitate immediately, if the cadium concentration is greater than 2.5 p.p.m. Examination of the precipitate shows that well-formed characteristic crystals develop, which are birefringent and exhibit parallel extinction. The crystals are rectangular in shape, having ends which are characteristically undeveloped.

Lower concentrations of cadmium are detected readily by concentrating about 1 ml. of the solution to 1 drop, transferring the drop to a slide with a capillary and carrying out the test as described previously. In this way, cadmium in concentrations less than 1 p.p.m. can be detected readily.

Zinc (1,000 p.p.m.) does not form crystals with the reagent. Nickel and copper (10 p.p.m.) alone with the reagent form no precipitate. The presence of nickel with cadmium causes the crystals to be tapered on both ends, the characteristic type of crystals with cadmium not being formed. The presence of copper causes rosettes to be formed. In the presence of Cr, Cu, Fe, Pb, Mn, Ni, and Zn (10 p.p.m.) rosettes are formed.

With a little practice on the part of the experimenter, this test will reveal more of the nature of the unknown solution than the spot test described for cadmium.

Chromium

Method A. With Diphenylcarbazide

About 0.8 p.p.m. of chromium may be detected in a solution containing 100 p.p.m. of Cd, Cu, Fe, Mn, Ni, Pb, and Zn.

1. Procedure

To one drop of sample on a spot plate add one drop of 20 per cent ammonium peroxydisulfate (ammonium persulfate) and one drop of 2 per cent silver nitrate. Let stand 2 to 3 minutes, then destroy any permanganate color that may have developed by adding one or two drops of 1 per cent sodium azide solution and stirring. Finally, add a drop of 1 per cent ethanolic diphenylcarbazide. A purple color, which usually fades rapidly, constitutes a positive test for chromium, while a colorless or yellow-brown solu-

tion is negative [see Feigl, "Qualitative Analysis by Spot Tests," p. 129 (1946)].

Copper

Method A. With Dithiooxamide

A concentration of 2 p.p.m. copper can be detected in the presence of 10 p.p.m. of Al, Ca, Cd, Fe, Ni, Mg, Mn, Pb, and Zn.

1. Procedure

Place a drop of 20 per cent malonic acid on No. 601 S and S test paper. Add four drops of the unknown (pH 3 to 7), a drop of 10 per cent ethylene diamine, and finally a drop of 1 per cent dithiooxamide reagent in 95 per cent ethanol. A green coloration indicates the presence of copper [see West, *Ind. Eng. Chem.*, Anal. Ed., **17**, 740 (1945)].

Iron

Method A. With 1,10-Phenanthroline

Iron (1 p.p.m.) can be detected in a solution containing 100 p.p.m. of Cd, Cr, Cu, Mn, Ni, Pb, and Zn.

1. Procedure

Place one drop of sample on a spot plate, add one drop of 10 per cent $NH_2OH \cdot HCl$ followed by one drop of 2 per cent ethanolic 1,10-phenanthroline and one drop of 20 per cent sodium acetate. Development of a pink color before or after addition of sodium acetate constitutes a positive test [see Feigl, "Qualitative Analysis by Spot Tests," p. 122 (1946)].

Lead

Method A. With Dithizone

Approximately 0.8 p.p.m. of lead can be detected in the presence of 100 p.p.m. of Cd, Cr, Cu, Fe, Ni, Mn, or Zn.

1. Procedure

Ten drops of sample solution, one drop of 10 per cent $NH_2OH \cdot HCl$, five drops of 10 per cent sodium citrate, one drop of 6 M NH_4OH, and three drops of 5 per cent KCN are added in that order to a semi-micro test tube (8 × 70 mm.). Then 0.25 ml. of 0.005 per cent dithizone in CCl_4 is added and the tube is stoppered and shaken vigorously for 10 sec. An orange or pink color in the CCl_4 is a positive test, while a colorless or pale green is negative [see Feigl, "Qualitative Analysis by Spot Tests," p. 57 (1946)].

Manganese

Method A. With Silver-Ammine Salt

The metal (1 p.p.m.) can be detected in the presence of 10 p.p.m. each of Cd, Cr, Cu, Fe, Pb, Ni, and Zn.

1. Procedure

A drop of solution containing the reagent is placed on No. 601 S and S test paper, then a drop of the test solution. If manganese is present, a black fleck appears. It is advisable to compare this spot with a blank.

Actually this spot test offers no advantage over the quantitative method for determining manganese. The quantitative method is quite sensitive and it takes only a few minutes to develop the permanganate color [see Feigl, "Qualitative Analysis by Spot Tests," p. 137 (1946)].

2. Preparation of Reagent

Concd. NH_4OH is added to a saturated solution of $AgNO_3$ until the initial precipitate is dissolved. An equal volume of NH_3 is then added.

Nickel

Method A. With Dimethylglyoxime

Nickel can be detected if present in a concentration of not less than 1 p.p.m. in a solution containing 10 p.p.m. each of Cd, Cr, Cu, Fe, Pb, Mn, and Zn. The concentration limit for nickel varies, depending on the amount of copper and manganese present.

1. Procedure

A drop of unknown solution is placed on a dry piece of No. 601 S and S test paper, which has been previously impregnated by immersion in a saturated solution of dimethylglyoxime in acetone. The paper is then soaked in a solution of $(NH_4)_2CO_3$ for a minute or two. A red fleck appears if nickel is present [see Feigl, "Qualitative Analysis by Spot Tests," p. 116 (1946)].

Zinc

METHOD A. WITH DITHIZONE

No test could be located in the literature which was sufficiently specific for zinc. The test with Cu^{++} and $Hg(SCN)^{=}$, suggested by Feigl, was found to be insensitive in the presence of large amounts of other metals. The test given below makes use of a precipitation with NaOH to remove most of the interfering metals. About 0.8 p.p.m. Zn can be detected.

1. Procedure

To 5 ml. of sample, add 1 drop of phenolphthalein, make alkaline with 4 M NaOH, and then add 0.5 ml. in excess. Centrifuge the precipitate, or allow to settle. Place 1 drop of the supernatant liquid in an 8×70 mm. test tube and add 1 drop of a methanol solution containing 2.5 per cent CS_2 and 10 per cent diethanolamine. Then fill the test tube ½ full of distilled water, add 1 drop of glacial acetic acid, and shake for 30 sec. with 0.25 ml. of 0.005 per cent dithizone in CCl_4. A purple or red color in the CCl_4 constitutes a positive test for zinc.

QUANTITATIVE METHODS FOR SELECTED METALS

The following procedures are based mostly upon existing methods. Literature references pertaining to the procedures are not listed because of the enormous number that would need to be included in such a bibliography. The reader is referred to books such as "Bibliography on Water and Sewage Analysis, Special Report No. 28," by Weil, Murray, Reid, and Ingols of the State Engineering Experiment Station, Georgia Institute of Technology; "Colorimetric Determination of Traces of Metals," by E. B. Sandell; "Trace Elements in Food," by Monier-Williams; and official methods proposed by many scientific organizations.

Although it would be almost impossible to check experimentally every method proposed in the literature for these metals, many were tried and their merits ascertained before accepting or rejecting any particular procedure. Admittedly, the methods can be simplified and short cuts introduced, if certain of the elements which interfere are not in the sample.

Many modifications, especially in regard to separations, were introduced by the writers to remove interferences. Some of the reagents are not yet commercially available, but have been recommended because of their desirable properties. It is believed that most of the new reagents will be available from some source in the near future.

Extractions are used primarily because of the simplicity, efficiency, and speed in separating small concentrations of constituents. Many separations can be carried out in much less time by extraction than by precipitation, volatilization, or electrodeposition.

All the methods proposed have been studied statistically to some extent with the exception of copper with 2,2'-biquinoline, in which case insufficient reagent was available. The method is included because of the specificity of the reaction of copper with 2,2'-biquinoline, combined with the reasonably good sensitivity and more desirable color (purple), if visual estimations of the copper concentration are to be made.

The use of pure reagents in these determinations cannot be over-empha-

sized. Water should be of high quality, distilled or redistilled, in order to remove traces of metals. The concentration of impurities tolerable depends on the particular determination. Water purified by ion-exchange is satisfactory in many cases, but the purity will depend on the quality of the source of water, the efficiency of the ion-exchange material, and the condition of the ion-exchange medium. Therefore, such water must be tested frequently for its purity.

Unless specified, any of the methods for digestion of organic material, as listed under the heading "Preliminary Treatment of Samples," may be used.

A comparison of the sensitivity of the various methods is shown in Figure 1. Although the absorbancy-concentration form of calibration curve was used throughout this work, other methods of plotting are usable.

Cadmium

Copper and iron are removed by extraction of the cupferrates with $CHCl_3$. Cadmium is separated from the remaining cations, including zinc, by extraction into $CHCl_3$ as the brucine-cadmium iodide complex. Cadmium is removed from the $CHCl_3$ by a dilute solution of HCl, the solution made basic with NaOH, and the cadmium extracted as the colored dithizonate with CCl_4.

1. Apparatus

1.1. Spectrophotometer or filter photometer equipped with a filter having maximum transmittance near 510 mμ.

1.2. Separatory funnels, 125-ml. Squibb type. Amber ware is best, but not essential.

1.3. Electrodeposition apparatus for standardizing the cadmium stock solution.

1.4. Amber volumetric flasks with ground-glass stoppers are desirable, but not essential.

2. Reagents

2.1. Acetic acid, glacial.

2.2. Bromine water. Distilled water is saturated with bromine.

2.3. Brucine sulfate reagent. Dissolve 2 g. of brucine sulfate in 100 ml. of a 5 per cent solution of acetic acid. Warm to 60° to 70° C. if necessary to dissolve the crystals.

2.4. Cadmium chloride standard solution. Prepare a stock solution so that the cadmium concentration is approximately 1,000 p.p.m. Pipet 25.00 ml. of the stock solution into an electrolytic beaker and make alkaline to phenolphthalein indicator with NaOH. Add sodium or potassium cyanide (10 per cent) dropwise until the precipitate of $Cd(OH)_2$ just dissolves. Dilute the solution to 100 ml. with water, and electrolyze for 30 min. at a current density of 0.6 amp. per sq. dm., then for 30 min. more at 1.2 amp. per sq. dm. Test for complete deposition by passing H_2S through a small sample of the electrolyte. If a yellow precipitate or color forms, continue the electrolysis until no cadmium remains in solution. Wash the plated platinum cathode in ethanol, dry at 110° C. for 3 to 5 min., cool, and weigh. Dissolve the cadmium in H_2SO_4 (1:1), wash the electrode, dry, and weigh as before. The difference in weight is the amount of cadmium present in the aliquot taken. If $Cd(NO_3)_2$ is used instead of $CdCl_2$, the sample taken for electrolysis must be fumed with H_2SO_4 to remove the nitrate.

2.5. Carbon tetrachloride, c.p. If the CCl_4 is not c.p., it must be redistilled. Pure CCl_4 may be obtained by refluxing the impure material with 5 per cent NaOH for 2 hr., separating the CCl_4 from the NaOH, washing the CCl_4 with water, drying over $CaCl_2$, and then distilling over CaO.

2.6. Chloroform, c.p.

2.7. Cotton. Metal-free absorbent cotton is prepared by digesting the cotton for several hours with warm 0.2 N HCl. The cotton is filtered on a Büchner funnel, washed with large volumes

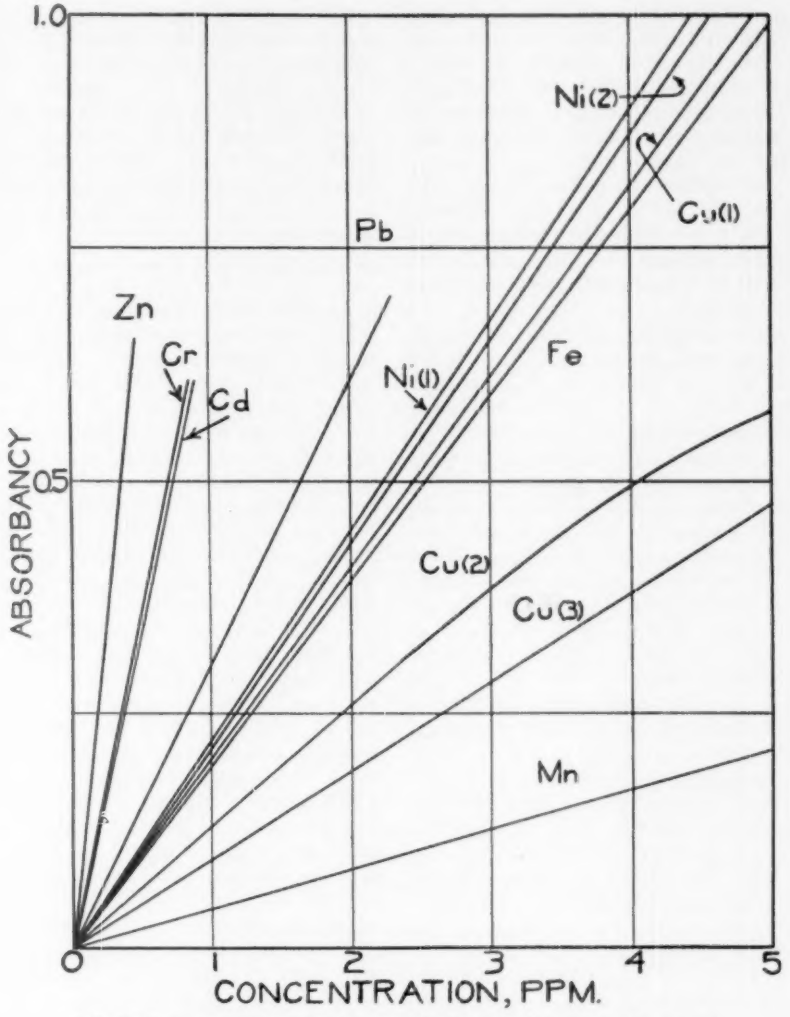

FIGURE 1.—Comparison of the sensitivities of various colored systems. (The band widths varied with the instrument. The cells were 1 cm.)

Zn—Zinc dithizonate, 535 mμ., Beckman (DU).
Cr—Chromium diphenylcarbazide, 540 mμ., Beckman (DU).
Cd—Cadmium dithizonate, 510 mμ., Beckman (B).
Pb—Lead dithizonate, 520 mμ., Beckman (DU).
Ni(1)—Nickel-1,2-cycloheptanedionedioxime, 445 mμ., Beckman (B).
Ni(2)—Nickel-dimethylglyoxime, 445 mμ., Beckman (DU).
Cu(1)—Copper-bis(2-hydroxyethyl)dithiocarbamate, 435 mμ., Beckman (DU).
Cu(2)—Copper-bis(2-hydroxyethyl)dithiocarbamate, blue filter, Fisher electrophotometer.
Cu(3)—Copper-2,2'-biquinoline, 545 mμ., Beckman (B).
Fe—Iron-1,10-phenanthroline, 508 mμ., Beckman (DU).
Mn—Manganese as permanganate, 525 mμ., Beckman (DU).

of distilled water to remove the acid completely, and dried.

2.8 Cupferron reagent, aqueous 1 per cent (ammonium salt of nitrosophenylhydroxylamine). Store in refrigerator or make up fresh for each determination.

2.9. Dithizone solution, 20 mg. dithizone per 100 ml. of CCl_4. Dissolve 0.100 g. of diphenylthiocarbazone in 500 ml. of pure CCl_4. Store in a dark bottle in a cool place, preferably in a refrigerator.

2.10. Dithizone solution, 10 mg. dithizone per 100 ml. of CCl_4. Purify the solution containing 20 mg. dithizone in 100 ml. of CCl_4 just before use as follows: Measure 75 ml. of the dithizone solution into a 250-ml. separatory funnel, add 75 ml. of distilled water, and then 8 ml. of 6 M NH_4OH. Shake well, discard the CCl_4 layer, and shake with portions of fresh CCl_4 until the CCl_4 layer becomes colorless. Add 75 ml. of pure CCl_4, make acidic with 6 M HCl and shake. Draw off the CCl_4 layer, wash with a 100-ml. portion of distilled water, and dilute the CCl_4 to 150 ml. The solution should be repurified if allowed to stand more than one-half day.

2.11. Hydrochloric acid, c.p., 0.5 M.

2.12. Hydroxylamine hydrochloride solution. Dissolve 10 g. of $NH_2OH \cdot HCl$ in 90 ml. of distilled water.

2.13. Methyl red indicator. A 0.1 per cent solution in 95 per cent ethanol.

2.14. Potassium iodide, c.p. Dissolve 10 g. of KI in 90 ml. of water.

2.15. Sodium citrate, c.p. Dissolve 10 g. of $Na_3C_6H_5O_7 \cdot 2H_2O$ in 90 ml. of water.

2.16. Sodium hydroxide, c.p. Dissolve 20 g. of NaOH in 80 ml. of water.

2.17. Water. Redistilled water free from all metals is essential for preparation of reagent solutions.

3. Preparation of Calibration Curve

Prepare a dilute cadmium solution from the stock solution so that the cadmium concentration is about 2.5 p.p.m. Pipet suitable volumes of this solution into 125-ml. separatory funnels so that from 3 to 17.5 micrograms of cadmium are present in the samples. Carry through the operations as described under *4*. The absorbancy-concentration calibration curve should be a straight line for this range of concentration.

4. Procedure

4.1. Separation of copper and iron. After removing the organic material in the original sample by digestion with H_2SO_4 and HNO_3 acids (see "Preliminary Treatment of Samples, 3.1") take an aliquot containing from 3 to 17.5 micrograms of cadmium, place in a separatory funnel, add 10 ml. of sodium citrate, one drop of methyl red indicator, and enough dilute NaOH to make the solution just basic to the indicator. Add 2 to 3 ml. of glacial acetic acid to adjust the pH to 3.0 to 3.8. Cool the solution by running cold tap water over the separatory funnel. Add 4 ml. of cold, fresh cupferron reagent and shake the solution with 10 ml. of $CHCl_3$. Allow the layers to separate, and add more cupferron until a white silky precipitate forms, which indicates that an excess of cupferron is present. Shake the mixture, allow the layers to separate, and discard the $CHCl_3$ layer. Repeat with a fresh 10-ml. portion of $CHCl_3$. Add 1 ml. of bromine water, mix, let stand 1 min., extract excess bromine water with 5 ml. of $CHCl_3$, and then add 1 ml. of $NH_2OH \cdot HCl$ solution.

4.2. Separation of cadmium from chromium, lead, nickel, manganese, and zinc. Five ml. of KI solution and 5 ml. of brucine sulfate reagent are added to the solution from 4.1. Extract three times with 15-ml. portions of $CHCl_3$ and collect the $CHCl_3$ layers in another 125-ml. separatory funnel. (This separatory funnel should have been cleaned thoroughly to remove metal ions by shaking in the funnel

about 10 ml. of dithizone solution with some pure water to which a few drops of dilute NaOH have been added, and finally rinsing with redistilled water.) Re-extract the cadmium into the aqueous phase with 20 ml. of HCl. Allow the phases to separate. Transfer the $CHCl_3$ layer to another clean separatory funnel and wash with 10 ml. of HCl. Discard the $CHCl_3$ layer. Add the wash solution to the other solution containing cadmium. Rinse the stopper and funnel with about 10 ml. of distilled water, and add it to the cadmium solution. After the addition of 30 ml. of NaOH to the cadmium solution, cool the solution to room temperature. Extract the cadmium with one 10-ml. portion of recently purified dithizone in CCl_4 (10 mg. dithizone in 100 ml. of CCl_4). Allow the layers to stand at least 1 min. before drawing off the CCl_4. Pass the CCl_4 through a small pledget of cotton in a short-stem funnel placed in a dry 25-ml. volumetric flask. Repeat the extraction with two 5-ml. portions of dithizone and one 4-ml. portion of fresh CCl_4. Dilute to volume with fresh CCl_4, mix, and measure the absorbancy of the solution at 510 mμ in a 1-cm. cell using CCl_4 in the reference cell.

During the extraction of the cadmium with dithizone it is advisable to darken the room, if amber glassware is not used. A towel may be wrapped around the volumetric flasks to prevent sunlight from affecting the light-sensitive solution. A blank is not necessary if the dithizone solution has been recently purified.

Chromium

Total chromium is determined colorimetrically with diphenylcarbazide after oxidation in acidic solution with ammonium peroxydisulfate. Interference from iron is eliminated by means of a preliminary separation with cupferron. Manganese, if present, is oxidized to permanganate, but the resulting color can be discharged with sodium nitrite without reduction of chromium.

1. Apparatus

1.1. Photoelectric filter photometer with green filter (ca. 540 mμ), or photoelectric spectrophotometer.

2. Reagents

2.1. Acetic acid, glacial.

2.2. Ammonium peroxydisulfate (ammonium persulfate) solution. Dissolve 20 g. $(NH_4)_2S_2O_8$ in 80 ml. of water. Prepare fresh every few days.

2.3. Ammonium sulfamate solution. Dissolve 5 g. $NH_4SO_3NH_2$ in 95 ml. of water.

2.4. Cupferron reagent. Dissolve 1 g. of the analytical reagent in 100 ml. of water. Keep in a cool place and prepare fresh every three or four days.

2.5. Diphenylcarbazide reagent. Dissolve 0.125 g. of diphenylcarbazide (Eastman) in 50 ml. of 95 per cent ethanol. Keep in a cool place and discard when the reagent turns brown.

2.6. Mixed acid, 3 N H_2SO_4 + 1.5 N H_3PO_4. Mix 83 ml. of concd. H_2SO_4 and 100 ml. of 85 per cent H_3PO_4 with water and dilute to 1 l. Add 0.01 N $KMnO_4$ solution dropwise to the hot acid until a faint pink color appears.

2.7. Potassium dichromate, 0.200 mg. chromium per ml. Dissolve 0.565 g. of dried $K_2Cr_2O_7$ in water and dilute to 1,000 ml.

2.8. Potassium dichromate, 0.00800 mg. chromium per ml. Prepare shortly before use by diluting 10.00 ml. of solution 2.7 to 250 ml.

2.9. Silver nitrate, 0.001 M. Dissolve 0.170 g. $AgNO_3$ in 1 l. of water.

2.10. Sodium nitrite solution. Dissolve 5 g. $NaNO_2$ in 95 ml. of water.

3. Preparation of Calibration Curve

Pipet 2.00, 5.00, 10.00, 12.00, and 15.00-ml. portions of the standard dichromate solution containing 0.008 mg. chromium per ml. into separate 100-ml. volumetric flasks and dilute to 60 ml. Add 10 ml. of mixed acid solu-

tion, then add from a pipet 2.0 ml. of diphenylcarbazide while swirling the flask. Dilute, mix, and measure the absorbancy at 540 mμ within 5 min. Plot an absorbancy-concentration curve. The color fades rapidly after 10 to 15 min., and the calibration curve is not linear at higher concentrations.

1. Procedure

4.1. Dilute an aliquot of the sample (see "Preliminary Treatment of Samples, 3.1") containing at least 10 micrograms of chromium to about 50 ml. and add 10 ml. of mixed acid solution. Slowly add sufficient cupferron to precipitate iron (note 1). Filter through a sintered glass filter and wash with cold water.

Transfer the filtrate to a 250-ml. conical flask, add 1 ml. of $AgNO_3$, 5 ml. of $(NH_4)_2S_2O_8$, a few glass beads, and heat to boiling. After boiling for 6 or 7 min., the brown turbidity resulting from partial oxidation of excess cupferron should disappear and leave a clear solution; if it does not, add an additional 5 ml. of $(NH_4)_2S_2O_8$ (note 2). Continue boiling for at least 20 min. after the last addition of $(NH_4)_2S_2O_8$ to insure complete decomposition of the excess oxidant, then cool the solution to room temperature. If the solution is colored by permanganate, reduce the MnO_4^- by carefully adding $NaNO_2$ solution one drop at a time, swirling for about 15 sec. between each drop; avoid any large excess of nitrite. Finally, add 2 ml. of ammonium sulfamate and allow to stand for 15 min. If manganese is absent, use of $NaNO_2$ and ammonium sulfamate is omitted.

Transfer the solution to a 100-ml. volumetric flask. If the chromium content exceeds 0.12 mg. (note 3), dilute to volume, mix, transfer an aliquot containing less than 0.12 mg. to a second 100-ml. volumetric flask, and add sufficient mixed acid solution to make the final H_2SO_4 concentration 0.3 N; if less than 0.12 mg. of chromium is present, the color is developed in the flask without further addition of acid. Develop the color by bringing the volume to about 70 ml. and adding 2.0 ml. of diphenylcarbazide while swirling the flask. Dilute to volume, mix, and measure the absorbancy at 540 mμ within 5 min.

4.2. Notes. 4.2.1. About 1 ml. of cupferron should be used for each milligram of iron present, but at least 3 ml. should be added in any case. It is also possible to precipitate the cupferrates in a 125-ml. separatory funnel and extract them by shaking with 20 ml. of $CHCl_3$.

4.2.2. If the manganese content of the sample aliquot exceeds 1 mg., some MnO_2 may be formed during the oxidation and the solution then does not clear completely. The MnO_2 can be reduced in the same manner as MnO_4^-.

4.2.3. A concentration of 0.12 mg. of chromium is approximately the limit for visual detection of the yellow dichromate color in 50 ml. of solution.

Copper

METHOD A. WITH BIS(2-HYDROXYETHYL)DITHIOCARBAMATE

Copper is separated from other metals by $CHCl_3$ extraction of its salicylaldoxime complex from acetic acid solution. The isolated copper is then determined colorimetrically using bis(2-hydroxyethyl)dithiocarbamate, which forms a yellow-brown water-soluble complex with cupric ion. The color is stable for about 1 hr. in solutions buffered within pH range of 3 to 6.

1. Apparatus

1.1. Photoelectric filter photometer with blue filter (ca. 435 mμ), or photoelectric spectrophotometer.

1.2. Separatory funnels, 125-ml. Squibb form with ground-glass stoppers.

2. Reagents

2.1. Acetic acid, glacial.

2.2. Ammonium hydroxide, 5 M. Dilute 333 ml. coned. NH_4OH to 1,000 ml.

2.3. Bis (2-hydroxyethyl) dithiocarbamate reagent. Solution A: Dissolve 4.0 g. of diethanolamine in 200 ml. of methanol. Solution B: Dissolve 1.00 ml. of CS_2 in 200 ml. of methanol. The colorimetric reagent is prepared fresh each day by mixing equal volumes of solutions A and B.

Impurities in the diethanolamine, methanol, or CS_2 cause the colored system to be instable. Therefore, purification of these chemicals may be necessary before preparation of the reagents.

2.4. Chloroform, c.p.

2.5. Copper-free distilled water for the preparation of reagents and dilution water.

2.6. Copper standard solution. Dissolve 1.000 g. of pure copper in 10 ml. of 1:1 HNO_3. Dilute, boil to expel oxides of nitrogen, and dilute to 1,000 ml. One ml. contains 1 mg. of Cu.

2.7. Hydroxylamine hydrochloride. Dissolve 10 g. of $NH_2OH \cdot HCl$ in 90 ml. of water.

2.8. Nitric acid, 1 M. Dilute 43.5 ml. coned. HNO_3 to 1,000 ml.

2.9. Salicylaldoxime solution. Dissolve 1 g. of salicylaldoxime (Eastman) in 5 ml. of 95 per cent ethanol and pour into 95 ml. of water heated to 80° C.

2.10. Sodium acetate. Dissolve 200 g. $NaC_2H_3O_2 \cdot 3H_2O$ in 800 ml. of water.

3. Preparation of Calibration Curves

3.1. Range 0 to 0.16 mg. copper per 100 ml. Dilute 2.00 ml. of standard copper solution to 100 ml. Pipet 2.00, 4.00, 6.00, and 8.00-ml. portions of this solution into 100-ml. volumetric flasks, add 10 ml. of HNO_3 and 10 ml. of sodium acetate to each, then dilute to about 50 ml. and add 1 ml. of mixed bis(2-hydroxyethyl)dithiocarbamate reagent. Dilute to volume, mix, and determine the absorbancy of these solutions at 435 mμ in a 5-cm. absorption cell. Use a blank containing all reagents except the copper solution in making the zero setting. Plot an absorbancy-concentration curve. The calibration curve is not linear unless a narrow spectral band is used.

3.2. Range 0 to 0.50 mg. copper per 100 ml. Dilute 5.00 ml. of standard copper solution to 100 ml. Pipet 2.00, 5.00, 7.00, and 10.00-ml. portions of this solution into 100-ml. volumetric flasks and proceed as in 3.1. The absorbancy of each solution is measured in a 1-cm. cell.

4. Procedure

4.1. Pipet an aliquot of the sample containing at least 10 micrograms of copper into a 125-ml. separatory funnel, and bring the volume to 20 to 25 ml. Add 5 ml. of NH_2OH, a drop of methyl orange, and NH_4OH dropwise with swirling until the color of the indicator just changes to orange. Acidify with 2.0 ml. of glacial acetic acid and add 5 ml. of salicylaldoxime reagent. After 1 or 2 min. extract with 25 ml. of $CHCl_3$, shaking for about 30 sec. Draw off the $CHCl_3$ layer into a second separatory funnel, add 2 ml. more salicylaldoxime reagent to the aqueous solution, and repeat the extraction with 10 ml. of $CHCl_3$. Add the second $CHCl_3$ extract to the first and discard the aqueous solution.

Shake the combined $CHCl_3$ extracts with 15 ml. of HNO_3 to remove the copper. Separate the $CHCl_3$ phase, and transfer the acidic solution to a 100-ml. volumetric flask (note 1). Extract the $CHCl_3$ once more with 10 ml. of HNO_3, discard the $CHCl_3$, and add the second acid extract to the first.

If the amount of copper in the original aliquot exceeds 0.5 mg., the solution is diluted to 100 ml., mixed, and an aliquot taken for the colorimetric measurement (note 2); otherwise, the color is developed in the original flask. Add 1 ml. of mixed bis(2-hydroxyethyl)dithiocarbamate reagent to the solution, which has been diluted to

about 50 ml. Then add immediately sufficient sodium acetate to bring the pH to 4 to 5; the amount required is 25 ml. unless an aliquot of the solution was taken, in which case a corresponding fraction of 25 ml. is used. Add 1 ml. additional bis(2-hydroxyethyl)dithiocarbamate reagent, dilute to volume, mix, and measure the absorbancy of the solution. A blank should be carried through the procedure and used to obtain the zero setting of the photoelectric instrument.

4.2. Notes. 4.2.1. For very small amounts of copper (0.05 mg. or less) it is preferable to make to a volume of 50 ml. rather than 100 ml. for colorimetric measurement. In this case, two 10-ml. portions of HNO_3 are used to extract copper from the $CHCl_3$, and the solution is buffered with 20 ml. of sodium acetate.

4.2.2. If a yellow-green color is easily visible in the $CHCl_3$, the copper content exceeds 0.5 mg. and an aliquot should be taken.

Method B. With 2,2′-Biquinoline

Copper may be determined directly upon the prepared solution without separating colored ions, such as chromium, iron, and nickel, unless these metals are present in concentrations greater than 15, 100, and 100 p.p.m., respectively, in the final copper solution. If necessary, the copper may be separated from the colored ions with salicylaldoxime as described in Method A.

1. Apparatus

1.1. Spectrophotometer or filter photometer equipped with a filter having a maximum transmittance near 545 mμ.

2. Reagents

2.1. Acetic acid, glacial.

2.2. 2,2′-biquinoline reagent. Dissolve 0.05 g. of the solid in 100 ml. of glacial acetic acid.

2.3. Copper standard solution. Dissolve 1.000 g. of pure copper in 10 ml. of 1:1 HNO_3. Dilute, boil to expel oxides of nitrogen, and dilute to 1,000 ml. One ml. contains 1 mg. of Cu.

2.4. Hydroxylamine hydrochloride. Dissolve 10 g. of $NH_2OH \cdot HCl$ in 90 ml. of water.

2.5. Malonic acid. Dissolve 20 g. of $CH_2(CO_2H)_2$ in 80 ml. of water.

2.6. Sodium acetate. Dissolve 20 g. of $NaC_2H_3O_2 \cdot 3H_2O$ in 80 ml. of water.

2.7. Water, copper-free for solution preparation and for dilution.

3. Preparation of Calibration Curve

3.1. Treatment. Pipet aliquots of a standard copper solution into 100-ml. volumetric flasks. The series should cover from 0.05 to 0.6 mg. of copper, if 1-cm. cells are used. Add 5 ml. of NH_2OH, 20 ml. of glacial acetic acid, 15 ml. of sodium acetate, 5 ml. of malonic acid, 20 ml. of the 2,2′-biquinoline reagent, dilute to 100 ml., and mix. The pH should be about 2.0. If more dilute copper solutions are to be measured, 5-cm. cells can be used.

3.2. Measurement. The solutions are measured at the analyst's convenience at 545 mμ. The reference cell contains a blank containing all the reagents except copper. Prepare an absorbancy-concentration calibration curve from the data obtained.

4. Procedure

4.1. Method I: Amount of chromium, iron, and nickel is less than 1.5, 10, and 10 mg., respectively, in the aliquot. Pipet an aliquot of the sample containing 0.05 to 0.6 mg. of copper into a 100-ml. volumetric flask (see "Preliminary Treatment of Samples, 3.1"). Add dilute NaOH until the metals present begin to precipitate or until the solution is about pH 3 to 4. Proceed as described in 3.1 and 3.2.

4.2. Method II: Amount of chromium, iron and nickel is greater than 1.5, 10, and 10 mg., respectively, in the aliquot. Pipet an aliquot of the sample containing from 0.05 to 0.6 mg.

of copper into a 125-ml. separatory funnel and dilute to a volume of 20 to 25 ml. Proceed with the separation of the copper from the other metals by salicylaldoxime, exactly as described under Procedure 4.1 in Method A. The HNO_3 solution containing the copper is then treated with 2,2'-biquinoline as described under 3.1 and 3.2 (Method B) without neutralizing the HNO_3 solution with dilute NaOH.

Iron

Iron is separated from interfering materials by extraction with diisopropyl ether from hydrochloric acid solution. The colorimetric determination is made using 1,10-phenanthroline in acetate buffered solution. The color is stable indefinitely.

1. Apparatus

1.1. Photoelectric filter photometer with green filter (ca. 508 mμ), or photoelectric spectrophotometer.

1.2. Separatory funnels, 125-ml. Squibb form with ground-glass stoppers.

2. Reagents

2.1. Diisopropyl ether.

2.2. Hydrochloric acid. Concd., free from iron.

2.3. Hydroxylamine hydrochloride. Dissolve 10 g. $NH_2OH \cdot HCl$ in 90 ml. of water. Prepare fresh every few days.

2.4. Iron-free distilled water for the preparation of reagents and for dilution water.

2.5. Iron standard solution, 1 mg. iron per ml. Dissolve 0.1000 g. pure iron wire in 10 ml. of 1:1 HCl and dilute to 100 ml.

2.6. Iron standard solution, 0.020 mg. iron per ml. Prepare shortly before use by diluting 10 ml. of the above solution to 500 ml.

2.7. 1,10-phenanthroline solution. Dissolve 0.5 g. of the monohydrate in 500 ml. of water heated to 80° to 90°C.

2.8. Sodium acetate solution. Dissolve 200 g. $NaC_2H_3O_2 \cdot 3H_2O$ in 800 ml. of water.

3. Preparation of Calibration Curves

3.1. Range 0 to 0.10 mg. iron per 100 ml. Pipet 1.00, 2.00, 3.00, 4.00, and 5.00-ml. portions of the standard iron solution (0.020 mg. per ml.) into 100-ml. volumetric flasks, and add 1 ml. of NH_2OH and 1 ml. of sodium acetate to each. Dilute to about 75 ml. and add 10 ml. of 1,10-phenanthroline. Dilute to volume, mix, and determine the absorbancy at 508 mμ after 10 min. in a 5-cm. cell. Use a blank containing all reagents except the standard iron solution to obtain the zero setting of the instrument. Plot an absorbancy-concentration curve. The color system obeys the Beer-Bouguer law.

3.2. Range 0 to 0.50 mg. iron per 100 ml. The procedure is identical to that given in 3.1, except that 5.00, 10.00, 15.00, 20.00, and 25.00-ml. aliquots of the standard iron solution are taken, and absorbancy measurements are made in 1-cm. cells.

4. Procedure

4.1. Transfer a 10.00-ml. aliquot of the sample to a 125-ml. separatory funnel and add 16.0 ml. of concd. HCl. Cool the solution, and then extract the iron with 25 ml. of diisopropyl ether, shaking for 30 sec. Draw off the lower acid layer into a second separatory funnel, and extract twice more with 10-ml. portions of ether. Combine the ether extracts in the original funnel and discard the acid layer.

Shake the combined ether extracts with 25 ml. of water to return the iron to the aqueous phase, and transfer the lower water layer to a 100-ml. volumetric flask. Repeat the extraction with a 10-ml. portion of water, adding this to the first aqueous extract. Discard the ether layer.

To the combined water extracts add 1 ml. of NH_2OH and 10 ml. of sodium acetate, and then complete the deter-

mination as described in 3.1. A blank should be carried through the procedure and used to obtain the zero setting of the instrument.

4.2. Notes. 4.2.1. If the iron content of the 10-ml. sample exceeds 0.5 mg., the aqueous extract from the ether separation is diluted to 100-ml. and an aliquot transferred to another 100-ml. volumetric flask for color development.

4.2.2. Failure to decolorize the HCl solution with three ether extractions should not be taken as evidence of incomplete extraction of iron. Copper, which is not extracted, gives a similar yellow color.

Lead

Lead is separated from other common metals by extracting with diphenylthiocarbazone from potassium cyanide solution. Only bismuth and thallium, both uncommon metals, react similarly. The carbon tetrachloride solution containing the lead dithizonate is washed with fresh cyanide solution to remove excess dithizone, after which the lead is determined by measurement of the red color of lead dithizonate. Iron and other substances which oxidize dithizone in basic solution are rendered harmless by preliminary reduction with hydroxylamine hydrochloride.

When the original sample contains sulfate, it is necessary to make an additional determination of lead in the insoluble residue from the acid digestion. This is accomplished by extracting the residue with ammonium acetate and determining the lead in this extract with dithizone.

1. Apparatus

1.1. Photoelectric filter photometer with green filter (ca. 520 mμ), or photoelectric spectrophotometer.

1.2. Separatory funnels, 125-ml. Squibb form with ground-glass stoppers.

2. Reagents

2.1. Ammonium hydroxide, lead-free.

2.2. Carbon tetrachloride, c.p.

2.3. Dithizone solution, 0.01 per cent in CCl_4. Dissolve 50 mg. of diphenylthiocarbazone in 500 ml. of pure CCl_4. Keep in the dark in a cool place.

2.4. Dithizone solution, 0.005 per cent in CCl_4. Prepare a purified solution as follows: Measure 125 ml. of 0.01 per cent dithizone into a 500-ml. separatory funnel and add 100 ml. of water, then 3 ml. of 5 M NH_4OH. Shake well and discard the CCl_4 layer. Add 125 ml. of pure CCl_4, then make just acidic with 6 M HCl and shake. Draw off the CCl_4 layer, wash it twice by shaking with 50-ml. portions of distilled water, and then dilute to 250 ml. with pure CCl_4. Keep in a cool, dark place and do not use if more than one week old.

2.5. Hydroxylamine hydrochloride. Dissolve 10 g. of $NH_2OH \cdot HCl$ in 90 ml. of water.

2.6. Lead-free distilled water for preparation of reagents and dilution water.

2.7. Lead standard solution, 1.000 mg. of lead per ml. Dissolve in water 1.600 g. of pure $Pb(NO_3)_2$ which has been dried at 110°, add 5 ml. of coned. HNO_3, and dilute to 1,000 ml. in a volumetric flask.

2.8. Potassium cyanide, 5 per cent. Prepare a lead-free solution as follows: Dissolve 25 g. of KCN in 50 ml. of water and shake with successive small portions of 0.01 per cent dithizone in $CHCl_3$ until the last portion is green. Then extract with five 20-ml. portions of fresh $CHCl_3$ to remove most of the dithizone from the aqueous solution. The small amount remaining after this treatment is not detrimental. Dilute the cyanide solution to 500 ml.

2.9. Potassium cyanide, 0.5 per cent. Dilute 10 ml. of the purified 5 per cent KCN solution to 100 ml.

2.10. Sodium citrate solution. Dissolve 10 g. of $Na_3C_6H_3O_7 \cdot 2H_2O$ in 90

ml. of water. Shake with 10 ml. of 0.01 per cent dithizone in $CHCl_3$ to remove lead, then filter.

3. Preparation of Calibration Curve

Prepare shortly before use a dilute lead solution containing 0.005 mg. of lead per ml. by diluting 5.00 ml. of the standard lead solution to 1,000 ml. Pipet 5.00, 10.00, 15.00, and 20.00-ml. portions of this solution into separate 125-ml. separatory funnels and adjust the volume of each to about 25 ml. A blank containing 25 ml. of water is also carried through. Add to each funnel 2 ml. of sodium citrate and 10.0 ml. of potassium cyanide, and then extract with 10 ml. of 0.005 per cent dithizone, shaking for 30 sec. Draw off the CCl_4 layer into another separatory funnel and repeat the extraction with successive 5-ml. portions of dithizone until the last portion shows no pink color; it should be colorless or pale green.

Wash the combined CCl_4 extracts with one 10-ml. portion of potassium cyanide, shaking for 15 sec., and discard the aqueous layer. Wash twice with 10-ml. portions of distilled water. Finally, transfer the pink CCl_4 solution to a dry 50-ml. volumetric flask; use a few milliliters of fresh CCl_4 to rinse the last drops of CCl_4 solution from the separatory funnel.

Dilute the solutions to 50.0 ml. with pure CCl_4, mix, and determine their absorbancy at 520 mμ within 30 min., using a 1-cm. absorption cell. Plot an absorbancy-concentration curve. The calibration curve should be linear.

Difficulty is sometimes encountered in extracting larger amounts of lead, due to the low solubility of lead dithizonate in CCl_4; this may cause red flecks of the complex to separate at the solvent-water interface. If necessary, this precipitate may be dissolved by persistent shaking with a few milliliters of fresh CCl_4 and added to the combined CCl_4 extracts.

4. Procedure

4.1. Transfer an aliquot of the sample (see "Preliminary Treatment of Samples, 3.1") containing between 10 and 100 micrograms of lead to a 100-ml. beaker and adjust the volume to 15 to 20 ml. Add 2 ml. of NH_2OH and 2 ml. of sodium citrate. Drop in a piece of red litmus paper and add NH_4OH dropwise with stirring until the solution is just basic to litmus. Then add 10.0 ml. of KCN, cover with a watch glass, and heat to boiling. Cool, and transfer the solution to a 125-ml. separatory funnel, using a minimum amount of water to rinse the beaker. Extract the lead with 0.005 per cent dithizone in CCl_4 and complete the determination exactly as described in *3* (above).

4.2. When the original sample contains both lead and sulfate, additional lead may be found in the ammonium acetate washings; this lead is to be determined and added to that found above. Transfer an aliquot of the ammonium acetate extract containing not more than 100 micrograms of lead to a 125-ml. separatory funnel, dilute to 25 ml. and add 10.0 ml. of KCN. A blank containing ammonium acetate and 10.0 ml. of KCN is prepared similarly. Extract the lead with dithizone and complete the determination as described above.

Manganese

Manganese is readily determined in small concentrations by the colorimetric determination of permanganate formed by oxidation of the manganese with periodate in acidic solution.

1. Apparatus

1.1. Spectrophotometer or filter photometer with a green filter having a maximum transmittance near 525 mμ.

2. Reagents

2.1. Manganese (II) sulfate solution, 1,000 p.p.m. Mn. Dissolve 16 g. of $KMnO_4$ (e.p. grade) in distilled water,

allow to stand several hours at 70° to 80° C., filter through a glass or asbestos-mat filter crucible, dilute to 500 ml., and standardize titrimetrically with sodium oxalate.* Calculate the volume of this solution necessary to prepare 1 l. of a solution containing 1,000 p.p.m. in manganese as follows:

$$\text{Vol. } KMnO_4 = \frac{910}{N \text{ } KMnO_4}$$

To this volume add 5 ml. of concentrated H_2SO_4, then $NaHSO_3$ solution (30 per cent) dropwise until the permanganate color disappears. Boil off the excess SO_2, cool, dilute to 1 l. with distilled water.

2.2. Nitric acid, 1:1.

2.3. Phosphoric acid, 6 M.

2.4. Potassium periodate, solid.

2.5. Sodium nitrite solution, 5 per cent. Dissolve 5 g. of c.p. salt in 95 ml. of water.

2.6. Sulfuric acid, concd.

3. Preparation of Calibration Curve

3.1. Treatment. Aliquots containing from 0 to 2.0 mg. of manganese (if absorbancy is measured in 1-cm. cells) or 0 to 0.5 mg. (with 5-cm. cells) are placed in 250-ml. conical flasks. To the solutions are added 25 ml. of water, 1 ml. of concd. H_2SO_4, 1.0 ml. of HNO_3, 20 ml. of H_3PO_4, and 0.3 g. of solid KIO_4. Heat the solution just below boiling for 10 min., cool, dilute to 100 ml. in a volumetric flask, and mix.

3.2. Measurement. The absorbancy (or transmittancy) of the colored solution is measured at 525 mμ. A green filter is used if the measurement is made with a filter photometer.

4. Procedure

4.1. Treatment of sample. Pipet an aliquot of the acid-digested sample (see "Preliminary Treatment of Samples, 3.1") containing from 0 to 2.0 mg. of manganese into a 250-ml. conical flask. Add 25 ml. of water, 20 ml. of H_3PO_4, and 0.3 g. of KIO_4. Then heat the solution just below boiling about 10 min., cool, dilute to 100 ml. in a volumetric flask, and mix.

4.2. Measurement. Transfer portions of the colored solution to each of two cells. Either add 1 drop of $NaNO_2$ solution or a crystal of solid $NaNO_2$ to the reference cell and mix thoroughly with a stirring rod to destroy the color due to permanganate. Proceed as in 3.2.

Nickel

Method A. 1,2-Cycloheptanedione-dioxime (Heptoxime) Method *

Nickel is determined colorimetrically with heptoxime. Iron and copper are removed by extraction of the cupferrates with chloroform. The nickel is separated from other ions by extraction of the nickel heptoxime complex with chloroform, re-extracted into the aqueous phase with hydrochloric acid, and determined in the acidic solution with heptoxime in the presence of an oxidant.

1. Apparatus

1.1. Spectrophotometer or filter photometer equipped with a filter having a maximum transmittance near 445 mμ.

1.2. Separatory funnels, 125-ml. Squibb form with ground-glass stoppers.

1.3. Electrodeposition apparatus for standardizing the nickel stock solution.

2. Reagents

2.1. Acetic acid, glacial.

2.2. Ammonium hydroxide, concd.

2.3. Bromine water. Distilled water is saturated with bromine.

2.4. Chloroform, c.p.

2.5. Cupferron, aqueous 1 per cent. Store in refrigerator or make up fresh for each determination.

2.6. 1,2-cycloheptanedionedioxime

* Fowler, R. H., and Bright, H. A., "Standardization of Permanganate Solutions with Sodium Oxalate." *Jour. Res.*, Natl. Bur. Standards, **15**, 493 (1935).

* New method of Ferguson and Banks, Iowa State College. Article in press for *Analytical Chemistry*.

(heptoxime) reagent. Ethanol (95 per cent) solution, 0.1 per cent. (Reagent not available commercially yet. Most likely obtainable from C. V. Banks, Iowa State College.)

2.7. Hydrochloric acid, 1.0 M.

2.8. Hydroxylamine hydrochloride solution. Dissolve 10 g. of $NH_2OH \cdot HCl$ in 90 ml. of water.

2.9. Methyl orange indicator. Aqueous solution containing 1 g. of indicator per liter of water.

2.10. Sodium hydroxide, c. p., 6 M.

2.11. Sodium tartrate solution. Dissolve 10 g. of $Na_2C_4H_4O_6 \cdot 2H_2O$ in 90 ml. of water.

2.12. Standard nickel sulfate stock solution. Dissolve nickel sulfate in distilled water so that the solution is about 1,000 p.p.m. in nickel. The concentration is best determined by electrodeposition of the nickel on a platinum gauze cathode. Transfer 50.00 ml. of the stock solution to a 250-ml. electrolytic beaker, neutralize with concd. NH_4OH, and then add 25 ml. in excess. Dilute the solution to about 125 ml. and electrolyze. If stationary electrodes are used, electrolyze at a current density of 0.2 to 0.3 amp. per sq. dm. When deposition is complete, wash the cathode with distilled water while lowering the beaker. Leave the current on during the operation. Detach the cathode, rinse again in distilled water, dip in ethanol, dry at 110° C. for 3 to 5 min., cool, and weigh. Dissolve the deposit by boiling the electrodes in concd. HNO_3 for at least 15 min., wash, dry, and reweigh the electrodes. From the amount of nickel in the aliquot, calculate the concentration of nickel in the solution.

3. Preparation of Calibration Curve

3.1. Treatment. Pipet aliquots of a standard nickel solution into 100-ml. volumetric flasks. The series should cover from 0.05 to 0.25 mg. of nickel, if 1-cm. cells are used. Add 25 ml. of HCl and 5 ml. of bromine water. Cool the flask containing the solution with cold water and add 10 ml. of concd. NH_4OH. Then immediately add 20 ml. of heptoxime reagent and 20 ml. of ethanol. Dilute to volume with distilled water and mix.

3.2. Measurement. Measure at 445 mμ 20 min. after addition of the reagent. The blank is prepared similarly except for omission of the nickel.

4. Procedure

4.1. Separation of copper and iron. Take an aliquot of the original sample prepared by digesting with H_2SO_4 and HNO_3 (see "Preliminary Treatment of Sample, 3.1") containing from 0.05 to 0.25 mg. of nickel, place in a separatory funnel, and add 10 ml. of sodium tartrate, two drops of methyl orange indicator, and enough NaOH to make the solution basic to the indicator. Add 1 ml. of acetic acid and cool the solution by placing the separatory funnel under cold running tap water. Add 4 ml. of fresh cupferron reagent and extract any precipitate formed with 10 ml. of $CHCl_3$. Allow the layers to separate, and add more cupferron until a white silky precipitate forms, which indicates that an excess of cupferron is present. Shake the mixture, allow the layers to separate, and discard the $CHCl_3$ layer. Extract again with 10 ml. of fresh $CHCl_3$ and discard the $CHCl_3$ layer. Add 1 ml. of fresh NH_2OH solution, mix, and let stand a few minutes.

4.2. Separation of nickel. Add 10 ml. of heptoxime reagent and extract the nickel complex with one 15-ml. and then two 10-ml. portions of $CHCl_3$. If the $CHCl_3$ layer is not colorless with the third extraction, continue until the $CHCl_3$ layer is colorless. Collect the $CHCl_3$ layers in a separatory funnel. Extract the nickel from the $CHCl_3$ by shaking with 15 ml. of HCl. After allowing the layers to separate, draw off the $CHCl_3$ layer into another separatory funnel and rinse.

4.3. Measurement. The solution is treated and the color measured as de-

scribed in 3.1 and 3.2. If desired, dimethylglyoxime may be used to develop the color with nickel. The conditions of color formation are identical with both reagents, but separate curves must be prepared. The rate of color development is slightly different for the two reagents so that with dimethylglyoxime, readings are taken at exactly 10 min. after addition of the reagent, whereas with heptoxime, readings are taken exactly 20 min. after addition of the reagent. Both systems are measured at 445 mμ. The heptoxime system is more stable. Dimethylglyoxime cannot be substituted for heptoxime in the extraction process under the conditions prescribed.

Zinc

Zinc is separated from other metals by extraction with dithizone and determined by measuring the color of the zinc-dithizone complex in carbon tetrachloride. Specificity in the separation is achieved by extracting from a nearly neutral solution containing bis(2-hydroxyethyl)dithiocarbamyl ion and cyanide ion, which prevent moderate concentrations of cadmium, copper, lead, and nickel from reacting with dithizone.

The color reaction is extremely sensitive, and precautions must be taken to avoid introducing extraneous zinc during the analysis. Contamination may arise from water, reagents, and from glassware (such as beakers and separatory funnels on which zinc has been adsorbed during previous use). Appreciable blanks are generally found, and the analyst must satisfy himself that these blanks are representative and reproducible.

1. Apparatus

1.1. Photoelectric filter photometer with green filter (ca. 535 mμ) or photoelectric spectrophotometer.

1.2. Separatory funnels, 125-ml. Squibb form with ground-glass stoppers.

2. Reagents

2.1. Acetic acid, glacial.

2.2. Ammonium hydroxide, zinc-free, 5 M. Commercial NH_4OH reagent usually contains zinc and is unacceptable. Prepare a concentrated solution by passing NH_3 gas from a cylinder into redistilled water and store the product in a plastic or a paraffin-lined bottle. If a cylinder of NH_3 gas is unavailable, c.p. ammonium hydroxide may be distilled using pyrex apparatus.

2.3. Bis (2-hydroxyethyl) dithiocarbamate solution. Dissolve 4.0 g. of diethanolamine and 1 ml. of CS_2 in 40 ml. of methanol. Prepare fresh every three or four days.

2.4. Carbon tetrachloride, zinc-free.

2.5. Dithizone solution, 0.01 per cent in CCl_4. Dissolve 50 mg. of diphenylthiocarbazone in 500 ml. of CCl_4. Keep in the dark in a cool place.

2.6. Dithizone solution, 0.005 per cent in CCl_4. Prepare a purified solution as follows: Measure 125 ml. of 0.01 per cent dithizone into a 500-ml. separatory funnel and add 100 ml. of water followed by 3 ml. of NH_4OH. Shake well and discard the CCl_4 layer. Add 125 ml. of pure CCl_4, make just acidic with HCl, and shake. Draw off the CCl_4 layer and wash it twice by shaking with 50-ml. portions of redistilled water, then dilute to 250 ml. with pure CCl_4. Keep in a cool, dark place and do not use if more than one week old.

2.7. Potassium cyanide solution. Dissolve 5 g. KCN in 95 ml. of redistilled water.

2.8. Sodium citrate solution. Dissolve 10 g. of $Na_3C_6H_5O_7 \cdot 2H_2O$ in 90 ml. of water. Shake with 10 ml. of 0.01 per cent dithizone in chloroform to remove zinc, then filter.

2.9. Sodium sulfide, 1 per cent solution. Dissolve 3.0 g. of $Na_2S \cdot 9H_2O$ in 100 ml. of water.

2.10. Sodium sulfide, 0.04 per cent solution. Prepare just before use by

diluting 4 ml. of 1 per cent Na_2S to 100 ml.

2.11. Zinc-free distilled water for preparation of reagents and dilution water. Ordinary distilled water usually contains traces of zinc, and should be redistilled using an all-pyrex apparatus.

2.12. Zinc standard solution, 1.000 mg. zinc per ml. Dissolve 1.000 g. of c.p. zinc metal in 10 ml. of 1:1 HNO_3. Dilute and boil to expel oxides of nitrogen. Transfer to a 1,000-ml. volumetric flask, dilute to volume, and mix.

3. Preparation of Calibration Curve

Prepare just before use a zinc solution containing 0.00200 mg. of zinc per ml. by diluting 5 ml. of the standard zinc solution to 250 ml., then diluting 10 ml. of the latter solution to 100 ml. with redistilled water. Pipet 5.00, 10.00, 15.00, and 20.00-ml. portions of the resulting solution into separate 125-ml. separatory funnels and adjust the volumes to about 20 ml. Another funnel containing 20 ml. of water is carried through as a blank. Add two drops of methyl red indicator and 2.0 ml. of sodium citrate to each; if the indicator is not yellow at this point, add NH_4OH a drop at a time until the indicator just turns yellow. Next add 1.0 ml. of KCN and then sufficient acetic acid a drop at a time just to turn the indicator to a neutral peach color.

Extract the methyl red by shaking with 5 ml. of CCl_4 and discard the yellow CCl_4 layer. Then add 1 ml. of methanolic bis(2-hydroxyethyl)dithiocarbamate. Extract with 10 ml. of purified dithizone, shaking for 1 min. Draw off the CCl_4 layer into another separatory funnel and repeat the extraction with successive 5-ml. portions of dithizone until the last one shows no change from the green dithizone color when viewed by transmitted light. Discard the aqueous layer.

Shake the combined dithizone extracts with 10 ml. of 0.04 per cent Na_2S, then separate the layers and repeat the washing with further 10-ml. portions of Na_2S until the unreacted dithizone has been completely removed, as shown by the aqueous layer remaining colorless or very pale yellow; usually three such washings are sufficient. Finally, remove any water adhering to the stem of the funnel with a cotton swab and drain the pink CCl_4 solution into a dry 50-ml. volumetric flask, using a few milliliters of fresh CCl_4 to rinse the last droplets from the funnel. Dilute to the mark with fresh CCl_4.

Determine the absorbancy of the zinc dithizonate solutions at 535 mμ and plot an absorbancy-concentration curve after subtracting the absorbancy of the blank. The calibration curve is linear if monochromatic light is used.

If large or erratic blanks are obtained despite the exercise of care in purifying water and reagents, it is probably caused by zinc adsorbed on the glass surface of the separatory funnels. These should be rinsed with 4 M HNO_3, then with distilled water, and finally shaken for several minutes with 5 ml. of sodium citrate and 5 ml. of dithizone. If possible, separatory funnels used for zinc analyses should be reserved for this purpose and not used for other determinations.

4. Procedure

4.1. Take an aliquot of the sample (see "Preliminary Treatment of Samples, 3.1") containing between 10 and 40 micrograms of zinc, transfer to a clean 125-ml. separatory funnel, and adjust the volume to about 20 ml. Determine the zinc in this solution exactly as described in 3 for preparing the calibration curve.

Generally not more than 30 ml. of 0.005 per cent dithizone should be needed to extract the zinc completely; if more is required, the aliquot taken contains too much zinc or the quantity of other metals which react with dithizone exceeds the amount which can be withheld by the complexing agent.

In the latter case, procedure 4.2 should be followed.

4.2. Separation of excessive amounts of cadmium, copper, and lead. This procedure should be followed when the quantity of these metals, separately or jointly, exceeds 2 mg. in the aliquot taken. Place the aliquot in a 100-ml. beaker, adjust the volume to about 20 ml. and the acidity to 0.4 to 0.5 N, by adding dilute HNO_3 or NH_4OH as necessary. Pass H_2S into the cold solution for 5 min. Filter off the precipitated sulfides using a sintered glass filter, washing the precipitate with two small portions of hot water. Boil the filtrate 3 or 4 min. to remove H_2S, then cool, transfer to a separatory funnel, and determine the zinc as described in 4.1.

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SIXTH INDUSTRIAL WASTE CONFERENCE

The Sixth Industrial Waste Conference is scheduled to be held at Purdue University, Lafayette, Ind., on February 21–23, 1951. The program is being planned so that it will cover the developments in waste disposal and utilization. A number of papers covering miscellaneous subjects, such as changes in laws and regulations, stream qualities, and stream surveys, are to be given. Separate sessions on particular subjects, such as food processing wastes, dairy wastes, metal wastes, laboratory procedures, and conservation of resources, are also planned.

Sponsored by the Civil Engineering Department of Purdue University, and several cooperating agencies, the five previous Industrial Waste Conferences of past years have been noteworthy for the high calibre and timeliness of the papers presented and the discussions provoked. As in former years, Don E. Bloodgood, professor of sanitary engineering at Purdue University, is chairman of the conference.

APPROACH TO THE WASTES CONTROL PROBLEM BY TWO INDUSTRIES *

I. PROCTER AND GAMBLE, CINCINNATI, OHIO

By Virgil E. Gex

Engineering Department

In such a problem as the approach to waste disposal, which affects the public interest, but whose short-term effect on a company's financial balance sheet is usually on the debit side, it would seem that the company's mental attitude toward the problem is equally as important as its physical approach to the solution. Accordingly, there is given herein a brief outline of Procter and Gamble's philosophical approach followed by a description of the physical approach to the industrial wastes problem.

The underlying philosophy guiding the company's thinking on waste disposal is that it wants to be a member in good standing of the community in which it operates. It is interested in things benefiting the community as a whole, because the company and its employees are members of the community and share in those benefits. Likewise, it is felt that actions contrary to the community interests by the company affect it as a member of the community, and detract from its status as a good neighbor and, eventually, as a successful business.

By extreme over-simplification, the company's approach to the waste disposal problem is divided into two phases:

1. Determining the scope of the problem.
2. Developing plans for solution of its various phases.

The first phase is being actively pursued by study of the over-all sewer systems at the Ivorydale and St. Bernard plants and by location and study of the departmental sources of contamination. In the study of the over-all sewer systems accurate sewer maps are being developed, flow data are being obtained for sewer outfall points, and analytical data are being obtained of flows at various points in the sewer systems.

The development of accurate sewer maps has in itself required considerable time. For a factory such as Ivorydale, which was started in 1885 and which has grown piecemeal ever since, there were, of course, no adequate records of sewer systems. All available records were searched for what information they might contain. This information was combined into skeleton sewer maps, and the information checked, for some of the sketchier systems, by the laborious method of following dye tracers from manhole to manhole. The result was what are believed to be reasonably accurate maps of no less than 27 different sewer systems for the Ivorydale and St. Bernard plants.

Volume and Character Studies

For determination of wastes flow, it has been possible to eliminate some sewers by reason of their inconsequential flow, and to deduce the flow of others from meters on water supply lines. This has reduced to 16 the number of sewer lines for which it has been necessary to install flow recording devices. Two of these, which discharge

* Presented at 1950 Annual Meeting, Ohio Sewage and Industrial Wastes Treatment Conference; Cincinnati, Ohio; June 28–30, 1950.

into municipal sewers and carry 25 per cent of the entire flow from the plants, have been fitted with permanent installations of flumes and recording flowmeters. Temporary recording flowmeters have been installed in the remaining 14 sewers. From these, flow data will be collected over an extended period of time to determine the average, maximum, and minimum flow rates.

Concurrently with this metering program, the wastes of the various sewer systems are being sampled to determine pH, B.O.D., dissolved solids, and suspended solids.

Waste Source Studies

For the second part of the study phase—examination of the processing sources of wastes—each operating department is being analyzed. A flow sheet and material balance is drawn up of all operations contributing to wastes. The operation of each department is then studied with a view to reducing the waste at the source, either by change in processing methods or habits, or by change in process equipment.

Reducing water contamination and waste load at the processing source is, of course, the best fundamental solution to the problem. The usual rules of good housekeeping and careful operation apply. In addition, the waste water from one process may sometimes be used in another department, with resultant decrease in waste load and a net saving economically. Change in equipment from conventional design may also be helpful, as well as economical. As an example of this, steam jet ejector systems can be designed to function satisfactorily using tube and shell intercondensers instead of the usual barometric intercondensers. Thus, the small amount of process material inevitably carried through the ejector does not contaminate the entire cooling-water supply to the system, but is condensed with the small amount of steam from the ejector. A considerable portion of the stock can usually be recovered from this concentrated mixture and the entire amount (2 to 3 per cent of the volume of the cooling water) is so small that it can be easily handled. Procter and Gamble is studying its existing ejector systems equipped with barometric condensers, to determine the advisability of replacing them with tube and shell intercondensers, from the viewpoint of economics as well as reduction of wastes load.

Pilot Tests Planned

In the second and most difficult phase of the work—the development of plans for solution to the wastes problem—little progress has been made as yet. After studies of the extent and character of the wastes have been completed, it is intended to work with a consulting engineering firm experienced in the industrial wastes field. In collaboration with this consultant, it is expected to develop various tentative methods of solution and to conduct pilot tests for treatment methods proposed. From the results of these tests, it is expected to be able to select, from comparison of first costs, operating costs, and performances, the plan which will produce the required results in the most economical manner. From this point on, the development of detailed design and construction will follow in normal fashion.

Summary

In summary, Procter and Gamble's basic approach to its wastes problem is divided into two major phases. First, the scope of the problem is being determined, by over-all measurements of sewage discharges and by individual studies of the processing sources of each waste. Based on the data thus obtained, and in conjunction with a consultant, it is planned to determine suitable treatment methods by pilot tests and to select the most advantageous

solution to the over-all wastes problem. By this procedure it is hoped to arrive at a sound answer to the wastes problem at a reasonable economic cost.

II. EMERY INDUSTRIES, INC., CINCINNATI, OHIO

By E. A. Emmer
Director of Engineering

The sewage and waste problem at the Emery Industries' plant is somewhat different from the average city plant in that there is no connection to city sewers. The plant sewers flow into Mill Creek, which in turn flows into the Ohio River. Discharges, therefore, would be subject to state and county requirements, which are, briefly: B.O.D. reduction by at least 65 per cent (provided that Cincinnati Pool has no less than 4 p.p.m. of dissolved oxygen), substantially complete removal of settleable solids, 45 per cent removal of suspended solids, and a pH of 7.0 or more.

The problem is further complicated by the three types of sewers, namely: storm, sanitary, and grease or process. This last type of sewer is desirably separate, in order to separate and recover grease and fatty acids contained therein by means of a large settling basin. Further, there is a well-water source in addition to city water.

As a preliminary examination of the sewage indicated a rather high B.O.D., it was thought that it might be cheaper to tie into the city sewer rather than to have a complete individual sewage disposal plant. Therefore, a complete survey was in order. Because the company's engineering and laboratory facilities were busy on plant expansion and production problems, it was decided to have the preliminary engineering done by an outside consulting engineering firm. The services of W. W. Carlton & Associates were engaged to make the survey.

Flow and Character Studies

The first step was to list all sources of sewage flow, of which there are four, and to take measurements at these points. Depending on quantity to be measured, various methods were used. Smaller quantities were measured into containers directly. Some quantities were determined by meter measurement of water supply, less losses in process or water fed to cooling towers. The losses in the latter case can be calculated fairly accurately. By far the greater quantity of sewage was measured by means of a wooden weir of the V-notch type, attached to the outlet. By reading the sewage height through the notch on an attached portion of a yardstick, the quantity flowing was easily calculated using standard coefficients.

Frequency of measurement was 12 to 15 times daily, throughout the 24-hr. period, with measurements not made at exactly the same times on succeeding days to determine if there were any regularity in flow. At the same time that quantities of sewage were determined, samples of sewage were taken. Samples at each outlet were apportioned according to the quantity flowing and the resultant mixtures for each 8-hr. period were analyzed. Thus, three composite samples daily were collected, extending over an approximate 10-day period. No results were taken when storm waters diluted the sewage.

Recommendations

After determining quantities over a given time, the results were plotted to determine an average flow. The quantities plotted showed considerable variation—from 138 to 409 g.p.m., with an average of 250 g.p.m.; except in a few instances, even minimums were above plant city water usage. This last, of

course, is accounted for by the plant well-water source.

The H. C. Nutting Company made all quantity determinations, took all samples, and ran all chemical tests. Chemical tests made were: dissolved and suspended volatile solids, dissolved and suspended nonvolatile solids, B.O.D., acidity as sulfuric acid, ether soluble fats, pH, and average flow for the period of the test. Tests indicated a rather wide variation in all the above, but with most results falling into a fairly narrow uniform range. As a result of the tests, the company's laboratories are presently engaged in research to try to reduce some of the variables and to find reasons for the extreme peaks in order to eliminate their cause. However, as previously mentioned, by using values from the narrow uniform range of results, or average results, the consulting engineers were able to make recommendations as follows:

1. Rearrangement of sewers.
2. Partial treatment of process sewage with tie-in to city sewers.
3. Complete treatment of process sewage with flow to Mill Creek.

The first recommendation had for its purpose three separate sewage systems; namely, sanitary, process, and storm sewers. The storm sewers would continue to flow to Mill Creek. The sanitary sewer would tie into the process sewage after treatment. Along with the process sewer, a larger grease trap was recommended, for it seems that the plant had outgrown the existing trap. The additional recovery of grease would pay for the larger trap within a year.

In regard to partial treatment, this would include removal of settleable solids after neutralization with lime, a treatment generally conforming with the requirements of Cincinnati for admission to its sewage system.

Complete treatment included the partial treatment as above, plus oxidation by aeration with drying of the sludge produced after digestion.

It is interesting to note that estimated operating costs of the complete treatment are 12 per cent lower than for partial treatment, with the sewage service charge. However, approximately 40 per cent more capital is required for complete treatment than for partial treatment and discharge to the city system.

Due to the topographical layout of the plant, with existing process sewers and proposed treating it will be necessary to pump all of the process sewage from several collecting points to the treating plant. Depending on where the tie-in to the city sewers can be made, it may be necessary to pump the sewage from the treating and settling tanks to the city sewers.

Summary

The foregoing covers in a very general way the approach and analysis of the sewage and waste problem at Emery Industries. It is by no means complete, but the company is working toward a solution. Thanks are due the city officials of Cincinnati, as well as those of the Ohio River Water Sanitation Commission, for their excellent cooperation.

EVALUATION OF WASTES DISPOSAL PROBLEMS IN THE PULP AND PAPER INDUSTRY *

I. PULP AND PAPER MILLS

By R. H. Savage

Research Director, Mead Corporation, Chillicothe, Ohio

This paper was prepared primarily for those representing pulp and paper mills at which pollution control programs have not yet been initiated. It is also intended for representatives of pollution control agencies, who must of necessity acquaint themselves with the particular problems of the various industries with which they must work.

The primary goal of any mill pollution control program is the development of ways and means to so condition the mill effluent that the receiving watercourse will meet the quality standards set up by the responsible water pollution control agency. To achieve this goal, there are numerous administrative, economic, and technical problems to be met and it is upon some of these problems that the following touches briefly.

Responsibility for the administration of a pollution control program usually falls upon the mill manager, who in turn invests the responsibility for the conduct of the technical work in the technical director or chief chemist. In most mills, especially the smaller ones, the laboratories are not equipped for research or special studies and are intended only for routine quality control testing. Laboratory facilities—and this includes working area, equipment, and service connections—are at a bare minimum and the personnel under the supervision of the chief chemist is usually without particular training in chemistry or engineering principles. The net result of this situation is that additional personnel with suitable qualifications must be provided and laboratory facilities augmented. Quite frequently, the expenditure for this last item will be considerable, depending, of course, on whether or not such expensive items as pH meters and B.O.D. incubators are necessary.

In order to evaluate the waste disposal problems of any mill, and to facilitate the pollution abatement program which may follow, it is necessary to collect certain basic mill data. First in the list of basic data are accurate diagrams showing the various mill operations and the flow of all materials throughout the mill. Although presenting no great problem, the collection of the information necessary to draw up the flow diagrams is a laborious job and entails many hours spent in the tracing of water and stock lines, questioning of operating personnel, and investigating the details of unfamiliar equipment. This is a job that is really never completed, as equipment and processing changes are continually taking place in pulp and paper mills and considerable effort must be expended in keeping the flow diagrams up to date.

Following the making of process flow diagrams is the equally important (and far less interesting) task of obtaining an accurate sewer layout. For those unacquainted with pulp and paper mills, it should be pointed out that the sewer systems of such mills are

* Presented at 1950 Annual Meeting, Ohio Sewage and Industrial Wastes Treatment Conference; Cincinnati, Ohio; June 28–30, 1950.

usually quite complex, especially in the older mills, and were not designed for investigative purposes. In most mills no up-to-date sewer layouts will be available. Here, again, is encountered a disagreeable and laborious task of personal investigation to locate the many branches of the system. Inasmuch as flow measuring and sampling stations will be needed later, it is desirable to determine the elevations of at least the main branches of the sewer system in order to evaluate the backing-up effects of these installations; this again is a time-consuming and sometimes difficult job.

Next in the securing of basic mill data comes the job of determining the character and amounts of wastes discharged from the various operating departments and the total pollution load from the mill. The magnitude of this job is dependent, of course, upon the type and size of the mill being surveyed; regardless of this, however, three troublesome problems are bound to arise in the survey work. These problems involve testing procedures, effluent sampling, and flow measurement.

The first of these problems can be disposed of rather simply—when in doubt as to what effluent tests to make or what procedures to use, consult with the agency responsible for pollution control in the State. The engineers of these agencies are usually quite willing to cooperate in matters of this kind, provided of course that they can find some free time in which to do so, and arrangements can generally be made to have some of the more specialized testing done in the agency laboratories.

Effluent sampling problems are, however, not so easily handled. Grab sampling is useful for equipment performance tests of short duration; further than that, the value of such a sampling method is questionable unless the sampling is very carefully conducted. The nature of pulp and paper mill operations is such that the flow rates and the character of effluent are continually changing; this condition indicates the need for samples taken at frequent intervals and in proportion to the flow at the time of sampling. There are several commercial samplers on the market which perform well under certain conditions; these samplers are, however, fairly expensive and it is sometimes difficult to justify the equipment and installation costs involved. Descriptions of operation and construction of a few samplers—very few—can be found in the literature and many ingenious samplers have been constructed by men in various mills. There is a great need for a compilation of all available information concerning automatic samplers for open channels and pipelines under pressure or running partially full; it is certain that such a compilation would be received with open arms by those engaged in pollution control work.

Published information on flow measurement is much more complete than that concerning samplers, and there is a wide selection of commercial equipment available for this purpose; nevertheless, the problem of obtaining accurate flow measurements is one which causes great concern in mill survey work. The flow measurement problems of different mills are quite varied and it is difficult to speak of these problems in generalities. Certainly all are familiar to some extent with the difficulties involved in maintaining meters in pipelines conveying water containing debris of various kinds and with the filling behind weir plates and other similar troubles. The installation of weirs, flumes, and other metering devices is expensive, the upkeep is high, and almost always these installations must be made while mill operations are suspended. As a matter of fact, scheduling of the construction or installation work sometimes is as difficult, or more difficult, than the actual selection of the measuring device to be used.

In conclusion, it is desired to touch briefly upon the collection of the final set of data needed to evaluate the waste disposal problem of a mill. These data are concerned with the ability of the receiving watercourse to assimilate mill wastes under various stream flow conditions and are essential in determining the extent of treatment required to condition mill effluents in order that the receiving water will be maintained in a satisfactory condition at all times. It is, of course, the responsibility of the pollution control agency to designate standards for the particular watercourse being considered; however, it is the responsibility of the mill pollution control group to collect sufficient data concerning stream characteristics to permit the adoption of adequate treatment and control measures. Many mills have found it necessary to secure the services of consultants for this highly specialized work; other mills have worked with the pollution control agency, either alone or in cooperation with other industries in the drainage area directly involved. Regardless of how the data are collected, the job will be tedious and, in many instances, costly; the problems involved in the field work and interpretation of data should not be underestimated.

II. WHITE PAPER MILLS

By H. C. Koch

Plant Chemist, Howard Paper Mills, Inc., Dayton, Ohio

Every trade has developed a special nomenclature and so it is with the paper trade. The title of this discussion refers to the "white paper industries." According to a dictionary of paper terms, "white paper" is a term commonly used by printers when speaking of any unprinted paper, regardless of its color. The term "fine papers" is also used for this same group of papers and the dictionary states that this is a broad term including papers intended for printing, writing, and cover purposes. It distinguishes these from wrapping papers and others not generally used for printing purposes. The latter are generally referred to as "coarse papers." Speaking of the major classification of paper products, it might not be amiss to mention a third group, the "paperboards," which are usually stiffer, heavier products having many uses, including containers and boxes.

Most of the paper mills in the Dayton area are dependent on outside pulp mills for their fiber materials and are, therefore, at times called "converting" mills. In these, the wood pulp is received in bales of clean, white square sheets resembling heavy paperboard. Speaking very generally for the moment, making paper from such pulp is a matter of mechanically beating the fibers to the required degree, adding the necessary nonfibrous material, and reforming into paper. The wastes are, therefore, different than those from pulp mills, where the wood is barked, chipped, cooked, washed, bleached, and separated into fibers for the production of pulp for the paper mills to convert into paper. In the self-contained paper mills, where wood pulp is prepared and subsequently used on the paper machines, the waste waters contain the dissolved and suspended solids of both the pulping and paper making operations. So far, mention has been made of only wood fibers and of paper made of wood fibers. However, the rag content papers are also in the classification of white or fine papers. Preparing the rag fibers for subsequent use in making paper also requires a cooking, washing, bleaching,

and fiber separation operation somewhat resembling the wood pulping operation. Here, also, are mills preparing the rag pulp, self-contained mills, and also mills receiving the rag pulp they use from outside sources.

This introduction has been given to define the scope of this paper and to illustrate the diverse operations to be found among the white paper mills. The different waste waters resulting from the various processes obviously require individual methods of attack.

Problems of Fiber Return

The following discussion will be limted to the waste water problems of the white or fine paper mills which receive their fibrous materials from outside sources—the converting type of mill.

Unless the materials removed from the waste waters in a clarification process can be sold, such a process obviously becomes an added overhead. In the converting type of paper mill, the more common procedure is to work towards retaining more of the waste solids in the paper itself. Otherwise, they must be sold to another mill making a paper or board with less strict specifications. The latter does not appear to be feasible for most mills. In most cases, if more of the solids are to be returned to the paper they must be returned to the same grade of paper and as quickly as possible. The fact that the white paper mills make 25 or more different grades often results in their changing grades several times in one 24-hr. run. With very strict specifications having very high minimums to meet, returning solids from one grade back to another grade is seldom possible. This is obvious in the case of changes of color.

Color and Grade Changes

When a change from a white to a color or a change from one color to another color is made, it is readily apparent that the water or the solids in the water cannot be used in the next grade. It may not, however, be so apparent that solids cannot be transferred from one grade to another, even though both be white.

The properties of the various grades of the papers made are dependent on many factors. The first factor is the fiber composition; that is, some grades require that the pulps used be from softwoods, whereas other grades require a combination of softwood pulps and hardwood pulps. The processes by which the pulp woods were cooked are also important factors in the properties of the papers produced from them. The properties of the papers are further modified by the chemicals, sizing materials, mineral fillers, and dyes that are added. For example, a soft paper, such as an offset paper, may carry an ash of around 12 per cent and may contain special fibers to give it the good printing qualities for which it is designed. Should a hard paper, such as a bond, with only 3 per cent ash follow it, the solids from the offset grade would be very undesirable in the bond. Mention of a few more examples, would be changes from the various duplicator, mimeograph, and book papers to envelope, map, check, and ledger papers.

Save-alls of various types are now in common use in the stock systems of the Fourdrinier machines making fine papers. In fact, many mills use not only the cylindrical-screen filtering types of save-alls, but also follow them with flotation-type save-alls. These do increase the total capacities of the machine water systems and, therefore, are factors influencing the problems connected with grade changes. To illustrate this further, a proposal to re-use more white water (water drained from stock at the machines) back into the system called for the installation of one or more small storage tanks. When the additional volume of water and the total solids such tanks would hold at a grade change was evaluated, this proposal was considered impractical.

Filter Aid Problem

It can be seen from this, also, that any save-alls for white water clarification which use filter aids, whether they be pulp or paper fibers, mineral solids, or soluble chemicals, must be evaluated in regard to their effect on the quality of the paper to which such filter aids may be returned. Certain mineral filter aids have been proposed, but their use for a fine paper system has been found to be impractical because they are low in color and gritty. Fine papers must meet high brightness specifications, among others, and that eliminates adding a lower brightness material. Gritty materials increase operating costs in wear on machine wires and other equipment while the paper is beng made and cause the paper to dull trimming knives and wear the printer's printing plates when the paper is used. Although the diatomaceous earths have been found useful as filter aids in some grades of papers, their color and abrasive qualities eliminate them from general use in the fine papers.

Closing of Water Systems

With the aid of save-alls and as a supplement to them, paper mills have long been closing up their white water systems to reduce their waste. That is, they have been replacing more and more fresh water with white water. Sometimes the expression "running the water system wide open" is used. It may be of interest to note here that, strictly speaking, this has not been the case for many years—probably beyond the memory of any paper maker of today. Probably most of the mills who are today working to reduce their wastes by closing the water systems are starting with paper machines already using 70 per cent of the water required over and over again. That is, the waters removed from the paper stock at the paper machine as the sheet is being formed are collected and pumped back to be re-used in further dilution of the stock at the various points in the machine system. The remaining water is used to fill the beaters.

In fact, the only fresh water used is that needed for the machine felt and wire cleaning showers and for the sprays needed to control foam. The volume of the waste water from the machine is, therefore, that required by the showers and sprays less that evaporated on the machine dryers. Further reductions in the wastes from the machines by further closing the white water systems entails either reducing the flow of fresh water to the showers or the substitution of white water. If white water is used, it is desirable to have it as free of suspended solids as possible. In fact, some type of relatively small individual filters for such showers would appear to be very valuable.

Nevertheless, the fresh water used does play a very important part in the maintenance of quality in the white papers. Because white waters have drained from the stock through fine-mesh wires, the fibers they carry are short and fine and, therefore, make poor substitutes for good stock. A second drawback to more re-use of white water is the fact that in spite of every effort for cleanliness, dirt and foreign matter does accumulate and when water is wasted it carries the fine dirt out with it. Cleanliness is more important in the fine papers than in any of the other grades.

A third valuable quality in fresh water is its lower temperature. Considerable heat is produced when fibers are refined. As the volume of the fresh water is reduced, the temperature of the stock can rise to undesirable levels; in fact, in these grades low temperatures are desirable. Then too, when the temperature of the system rises, conditions become more favorable than ever for the growth of microorganisms and their concomitant slime growths, which are so costly in lost production.

Finally, although dissolved chemicals (such as alum) are necessary in the process, a continuous concentration of the dissolved chemicals, as results from further closing the system, is not desirable.

In conclusion, the further reduction of wastes from the white paper mills in the more desirable manner—that is, by recovery and sale as paper—does present many problems. This evaluation of the waste disposal problems has presented no solutions, but a problem to be solved must first be recognized. It will be interesting to see what time and work will develop.

RADIOLOGICAL HEALTH COURSE

An in-service training course in Radiological Health is being offered by the School of Public Health, University of Michigan, on February 5–8, 1951, at Ann Arbor, Mich. This is one of a series of in-service, non-credit, training courses offered by the University's School of Public Health. The present course is planned to serve all public health personnel. It is not a course in civilian defense, although it will provide public health workers with information that should aid them in more readily understanding some of the problems in which they might some time receive civilian defense training.

The course is designed to clarify and coordinate information on a subject deemed to be of increasing importance to public health workers. Of particular interest to those in the fields served by THIS JOURNAL are the sections dealing with protection in use of low-level and medium-level radioisotopes, as well as with the disposition of wastes from radioactive sources.

APPLICATION OF THE OCO WATER SYSTEM TO PAPER MILL WHITE WATER RECOVERY *

By George C. Ehemann, L. K. Burnett, and John C. Waddell

Plant Engineer, Quality Control Manager, and Development Chemist, respectively, The Ohio Boxboard Co., Rittman, Ohio

Recovery of industrial process water has long been very desirable and at the same time very difficult to accomplish. It is desirable because of the need (1) to conserve diminishing supplies of fresh water, (2) to recover heat and material going to waste with the used water, and (3) to eliminate pollution caused by dumping such waste water into streams. It has been difficult to accomplish because of a lack of positive low-cost methods of recovering the suspended solids and conditioning the used water so that it is entirely suitable for re-use.

Recovery of paper mill industrial process water, commonly called "white water," has been especially difficult because of the enormous quantities of this water used in the papermaking process and because of the lack of equipment which would render it completely free of suspended fibers and fillers. Conversely, a satisfactory solu-

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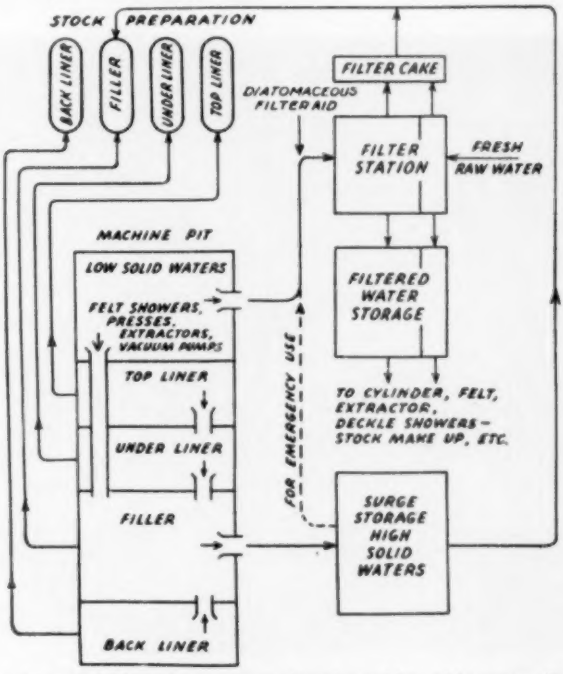

FIGURE 1.—Schematic flow sheet of paperboard machine white water filtration system.

tion to this problem is especially desirable in the paper industry because of the value of the fibers, filler, and heat that are wasted and because of the increasing pressure from government bodies for abatement of stream pollution caused by paper mill effluent.

The OCO Water System

The OCO water system has been developed as an answer to recovery of process water in general and especially for recovery of paper and paperboard mill process water or white water. Essentially, the OCO water system is a program of selective return of high-solids process water to the system and positive filtration of the remaining low-solids white water so that the solids can be recovered as furnish, and the filtered water is of such sparkling clarity that it is freer of suspended solids than most paper mill fresh-water supplies.

Use of Low-Volume Showers

One of the largest uses of fresh water in paper mills is in showers used to clean felts and wires (see Figure 1). The use of high-pressure low-volume showers in place of conventional low-pressure high-volume showers offers real economies in the amount of water used for this purpose. However, the small nozzles of these showers preclude their use on any water not substantially devoid of suspended solids. Many fresh water supplies have proved unsuitable for use in these low volume showers. OCO filtered water is entirely satisfactory for low volume showers and, thus, makes large economies practical in total water usage in a paper mill.

Plate and Frame Filter

The filtration unit used in the OCO water system is a pressure-type plate and frame filter (Figure 2) using a

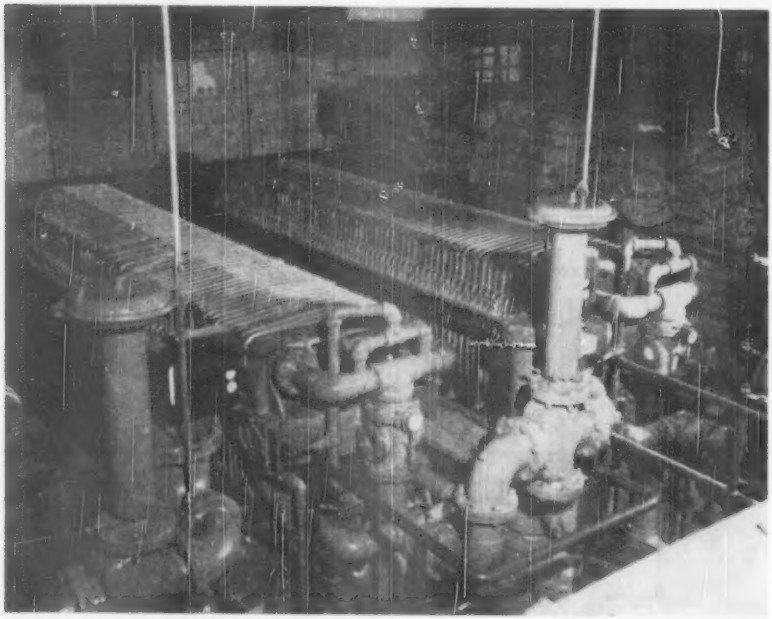

FIGURE 2.—Pressure-type plate and frame filters used in the OCO water system.

diatomaceous silica filter aid. In exhaustive laboratory and pilot plant studies, this type of filter was found to have the distinct advantage of positive filtration at all times. The filtrate at any fractional flow rate is of sparkling clarity and substantially devoid of suspended solids. With proper filter aid addition, economical filter cycles can be attained at high flow rates.

In the plate and frame press, a fabric filtering medium is held between an aluminum alloy plate and a hollow frame assembled to form a cell unit (see Figure 3). A number of these cells in parallel form the filter. Each plate and frame has side lugs, which support it on parallel horizontal bars. The units may be slid back and forth on these bars during cleaning. One end of the filter is closed by the head of the press, the other end by a heavy plate, against which clamping pressure is exerted. Holes drilled through the plates and frames form longitudinal channels in all four corners of the press when it is clamped together. The water to be filtered is pumped into the bottom channels and passes up through ports into the hollow frames. From here, the water passes through the filtering media, leaving the suspended solids behind in the hollow cake space. The filtrate passes up through spaces in the pyramided surface of the plates and out through ports into the top channels for discharge. A filter cycle is terminated when either the cake space in the hollow frames is filled or the resistance to flow through the cake exceeds the supply pressure. When a cycle is ended, clamping pressure is released and the press is opened up. The cake, which is formed on the filter media (Figure 4), is dropped from each frame successively and the entire filter is hosed clean in preparation for the next cycle.

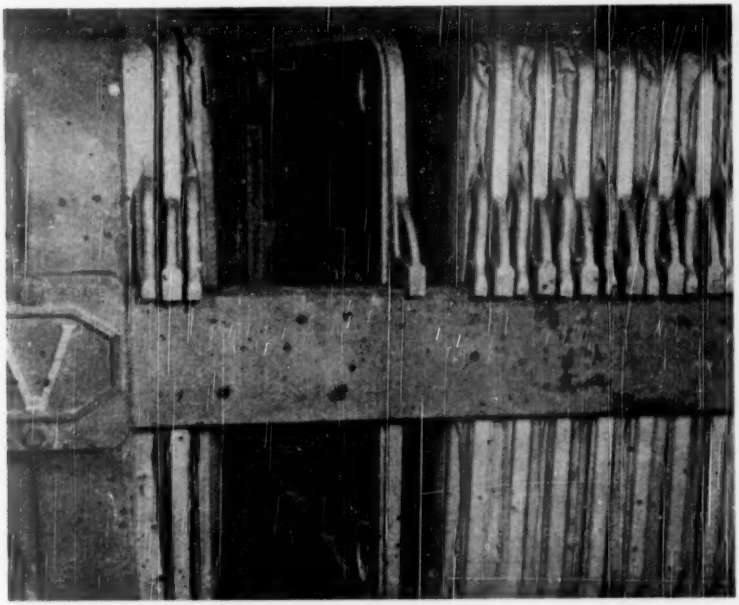

FIGURE 3.—Fabric filtering medium held between aluminum alloy plate and hollow frame forms cell unit.

Where only one filter is used, sufficient storage capacity must be provided ahead of and after the filter to store up effluent and filtered water while the filter is being cleaned and prepared for the next cycle. Where several filters are used, one is taken down at a time so that filtering is continuous. However, surge capacity ahead of the filters is desirable to make it possible to filter at a constant rate regardless of the normal variations in mill effluent rate. Similarly, storage capacity after the filters is desirable to prevent mill shutdowns due to temporary breakdowns in the filter plant.

To prevent immediate blocking of the filtering media by the fines and colloidal matter in the white water, some type of filter aid must be used. Diatomaceous silica lends itself readily to this application. The irregular-shaped diatoms arrange themselves in the cake in an interlaced fashion that entraps even the smallest particles of foreign matter in the water. At the same time, millions of microscopic interstices are formed that permit unobstructed flow of water through the cake. The bulky, porous cake formed when the diatomaceous silica is dispersed through the water is one of the factors upon which the effectiveness of this system is based. The open spaces in the cake constitute nearly 90 per cent of its surface area, yet the openings are so tiny that even bacteria are filtered out. Those slime and odor producing microorganisms which do pass through may be easily controlled by chlorinating the filtrate.

Recovered Solids

The concentration of the bacteria in the cake of recovered fiber and filler offers a convenient and economical place to sterilize the stock to be returned to the system, either by chemical or heat treatment. The presence of diatoms in the cake frees the stock so

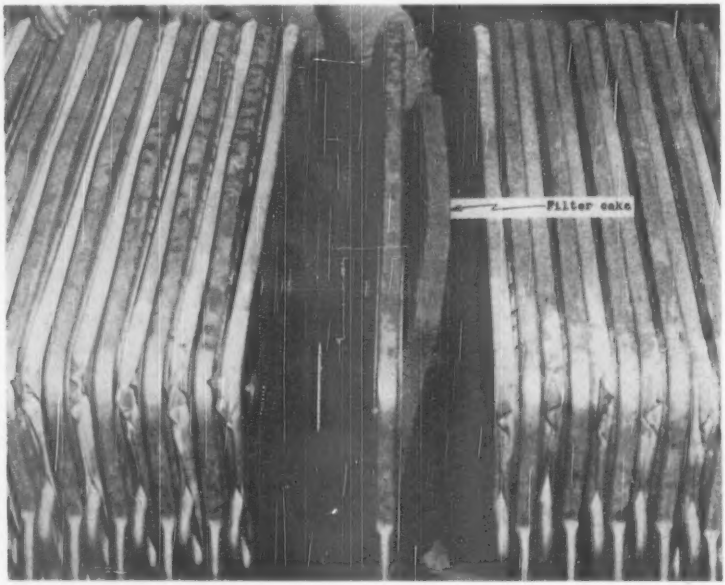

FIGURE 4.—Filter cake formed on the media is removed from each frame in preparation for next cycle.

that it does not cause the drainage problems sometimes associated with recovered stock.

Ohio Boxboard Installation

The Ohio Boxboard mill at Rittman, Ohio, operates four cylinder paperboard machines, producing 500 tons a day of folding carton, container liner, and specialty boards. Fresh water is supplied by six wells and a creek. The effluent from the four paperboard machines is collected in a common ditch, which conveys it to settling tanks. Past practice has been to return partially clarified water from this settling system for re-use in the mill. In order to determine the applicability of the OCO water system on a mill scale, the principles of the system have been applied as completely as possible on two of the four paperboard machines. These two machines are arranged to return high-solids white water to the beater room and to discharge low-solids water to the recovery system. They have also been completely equipped with high-pressure low-volume showers. Oscillating jet-type showers with 3-in. nozzle spacings are used on the cylinder molds. The same type showers with 1.5-in. spacings are used on the felts. Two showers on the inside and a whipper are used on the top felt. Two showers on the inside and a shower and a whipper on the outside are used on the bottom felt. To prevent possible loss of vacuum in the suction box, the felt is kept thoroughly wet by water collected in a pan under the whipper roll.

Part of the partially clarified water from the settling system is passed through three plate and frame filters. The filtrate is used exclusively on the low-volume showers; the filter cake is mixed with the sludge from the settling system and returned to the mills as filler furnish.

Operation Data

The effluent white water going to the settling system is treated with approximately 70 p.p.m. of alum to aid flocculation. It is then pumped to two 225,000-gal. settling tanks (Figure 5), where the solid content is reduced from 5 to 10 lb. per 1,000 gal. to about 0.5 lb. per 1,000 gal. by coagulation and settling. Part of the partially clarified water drawn continuously off the top of the settling tanks goes to the plate and frame filters and the remainder goes to a reservoir for re-use in the mill.

The portion to be filtered flows continuously into two 750-gal. slurry mixing tanks where filter aid addition proportional to flow rate is made by a dry feeder. The filter aid is dispersed through the white water by agitation and the mixture is pumped to three 1,000-sq. ft. plate and frame filters. Each 1,000-sq. ft. filter press consists of 65 cell units as described previously. Filter papers placed over the filtering medium eliminate the need for precoating the press with a heavy layer of filter aid before each cycle. This practice prevents plugging of the filter medium by colloidal matter, thus lengthening the filter cycle and the life of the medium. It also provides more cake space and lessens the task of cleaning up after a cycle. The filter paper may be die cut from any light-weight or heavy paper with the proper porosity. Nine-point strawboard, Kraft, and semi-chemical corrugating medium have been found equally effective.

A rotameter on the inlet to each filter holds the flow rate constant at any preset value. During the initial phase of the cycle, the resistance to flow is very slight. This resistance increases slowly as the cycle progresses and the rotameter operates a valve to let more of the pressure developed by the pump force the water through the filters. The filters are connected in parallel across common supply and discharge lines. Thus, the operation of any one filter is independent of all others. For a 3- to 5-min. period at the start of a filter cycle, the filtrate is cloudy and

not suitable for use on low volume showers. Provision is made for recirculation back to the slurry mixing tanks during this period. When sparkling clarity is attained, the operation is shifted directly to service.

At the end of a cycle, the filter press is opened and the cakes, including the papers on which they are formed, are dropped into a chest, thoroughly mixed with the sludge from the settling tanks, and returned to the mill as filler furnish. At present, the time used to clean and re-paper a filter is 90 min. Proposed engineering changes should reduce this by one half.

The filtered water discharges directly to a high-pressure pump, which supplies water to the low-volume showers on the two paperboard machines

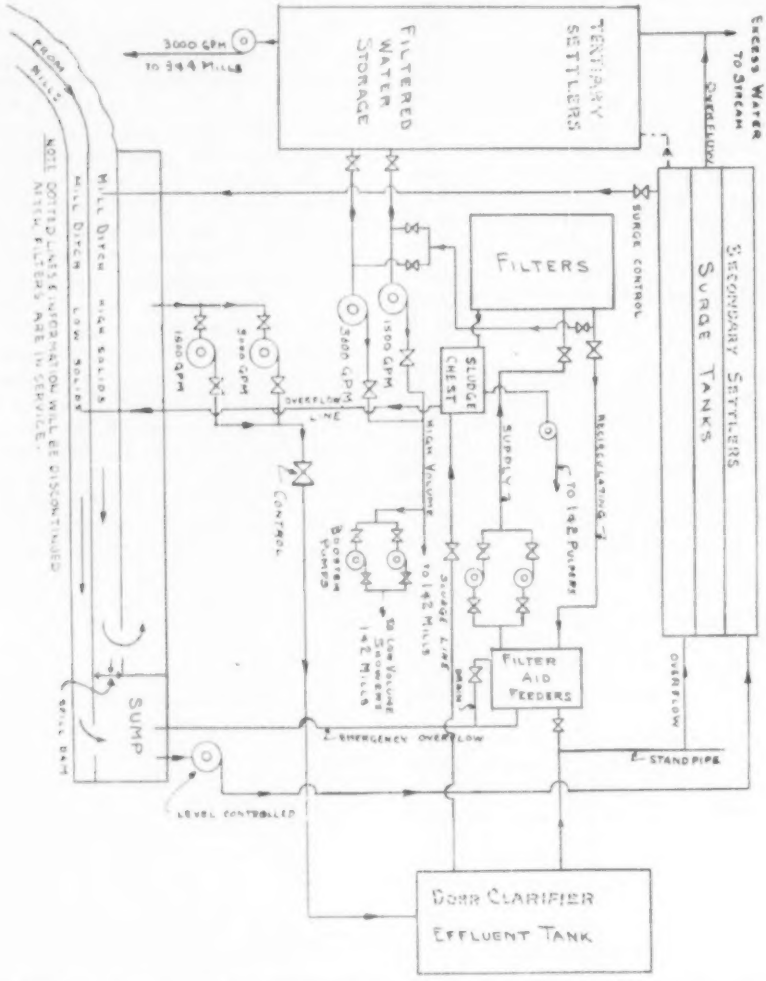

FIGURE 5.—Schematic flow diagram for white water filtration and settling system.

thus equipped. One is a 75-ton, 96-in., 7-cylinder machine. The other is a 120-ton, 120-in., 7-cylinder machine. Filtered water is supplied at 150 lb. per sq. in. to seven cylinder-mold showers, two top-felt showers, and three bottom-felt showers on each machine. The volume required is approximately 480 g.p.m., which is supplied by two filters. The third filter is held idle for stand-by use. At the flow rates used, the length of filter cycle has averaged 16 hr., with a filter aid addition of 4 lb. per 1,000 gal. Analysis has shown no measurable suspended solids in the filtered water. The filtered water does contain considerable dissolved solids, but this has not affected shower operation. It is believed that any action dissolved solids may exert on board characteristics can be overcome by chemical treatment when necessary. Microbiological analysis has shown an average removal by the filter of 85 to 90 per cent of the slime- and odor-forming bacteria in the white water. The bacteria so removed are concentrated in the filter cake and are, therefore, subject to economical control. Present practice is to use 0.125 lb. of bactericide per 100 lb. of solids in the combined settling system sludge and filter cake. Bacterial growth in this mixture is further controlled by the use of temperatures up to 180° F. in the hydrapulpers, where it is fed as furnish.

The concentration of bacteria in the filter cake will cause sliming of the filter cloths if not controlled. Therefore, about 0.015 lb. of bactericide per 1,000 gal. of water is added in the slurry mixing tanks to prevent this slime growth.

That portion of the total bacteria still remaining in the filtrate is controlled by chlorination. An attempt has been made to carry a residual of 0.3 p.p.m. in this water as it goes to the mill; the chlorine demand is normally within the range of 13 to 15 p.p.m. Slime measuring units are used to determine the rate of slime accretion at various points throughout the mill water system. No growth has been evident in the filtered water since the installation of chlorine control.

The filter cake, at a consistency of approximately 35 per cent, is added to the sludge from the settlers (consistency approximately 1 per cent). The sludge is drawn from the settlers at a rate of 220 g.p.m. The freeness of the combined sludge and filter cake is approximately 60 on the Canadian Standard Freeness scale.

During the four months in which the system has been in operation, the temperature of the filtered water has averaged 30° F. higher than the fresh water available to the mill.

Low-volume high-pressure cleaning of felts and cylinders has been proven completely satisfactory except for bottom felts. Although this latter use has not been completely satisfactory, the difficulties have been only minor and presumably due to dissolved alumina. Corrective facilities have been provided. Since using the high-pressure showers and chlorinated filtered water, felt life has been increased 300 to 500 tons per felt, or approximately 10 to 15 per cent.

A saving of approximately 30¢ per ton of board has been realized by furnish changes made possible by increases in brightness of the board when using OCO filtered water in place of fresh water. Some reduction has also been made in the amount of titanium used in top liner furnishes.

The National Council for Stream Improvement (of the Pulp, Paper and Paperboard Industries), in a recently published bulletin, states that the build-up of dissolved and colloidal matter and fines due to recirculation is favorable to slime formation, but that it is the slime itself and not the fines and colloidal materials that decrease freeness. The experience reported on here would seem to bear out these findings because no trouble on

the machines has yet been found traceable to the re-use of recovered solids.

Cost

The cost of a recovery unit of this nature will, of course, depend entirely on the size of the installation and on the adaptability of existing facilities. In addition, the physical layout of the mill will have a big effect on the number of pumps and the amount of piping required. Assuming that a system can be closed by the installation of one filter, the following equipment would be necessary: one 1,000-sq. ft. plate and frame filter press; one set of 65 filter cloths; one flow controlling rotameter; one slurry mixing tank and dry feeder assembly; and two 40-hp. centrifugal pumps. Total cost for this equipment is approximately $15,000. To this figure must be added the cost of low-volume showers, valves and piping, stand-by pumps, cake handling equipment, and chlorine dispensing equipment. These additions would raise the cost to somewhere between $25,000 and $50,000. It is estimated that the total installation cost of a recovery unit of sufficient size to completely service a 500-ton paperboard mill would be in the neighborhood of $100,000.

The operating costs for a three-filter unit include a labor charge of approximately 10 hr. per 8-hr. turn. The cost of materials used (filter aid, filter papers, alum, and chlorine) amounts to approximately $139.00 per m.g. recovered. In the present case, the savings resulting from heat recovery alone just about equals the cost of these materials.

Conclusions

Based on four months of operating experience of the above-described OCO water system at the Ohio Boxboard Co. mill, it is concluded that it offers a practical solution to the recovery of industrial process water, especially paper mill white water. The filtered water from the plate and frame filters has proved to be entirely satisfactory on low-volume high-pressure showers, thus permitting the use of these showers, with resultant economies in water requirements. Experience with the use of the system applied to two of the paperboard machines has been convincing enough to indicate the advisability of proceeding as rapidly as possible to extend the principles of the system to the other two paperboard machines. It seems possible that when this is done and only low-solids water is returned for filtration, presettling of the mill effluent may be eliminated. It is believed that further application of this system also may make it possible to pass all of the board mill process water, whether fresh or returned, through the OCO filters so that there will be only one supply of water—OCO filtered water. It is further believed that it is entirely possible, through use of this system, to recover all of the suspended solids, which have previously been going to the stream, and ultimately to discharge to the stream only filtered water, if any, devoid of suspended solids.

DISCUSSION

By H. W. Gehm and A. J. Palladino

Technical Director and Midwestern Resident Engineer, respectively, National Council for Stream Improvement (of the Pulp, Paper and Paperboard Industries), Inc.

From the stream pollution standpoint, the benefit of the OCO system stems more from the reduction in volume of process water than from the reduction in fiber losses through the pressure filters. This is apparent from the fact that the filters remove only from 5 to 10 per cent by weight of the

suspended materials that can be removed in the presettler underflow. In regard to solids removal, therefore, the bulk of the work is accomplished by the presettler. Moreover, numerous experiments with paperboard waste waters have indicated that complete clarification, such as accomplished by the OCO system, effects a 40 per cent B.O.D. removal, whereas plain settling alone removes 25 per cent of the B.O.D. The protection against stream pollution due to suspended solids removal in the filters is small, therefore, although definite.

However, the reduction in volume of process water inherent in the OCO system is important, in that this in effect increases the storage capacity of white water tanks. Control over the white water system is correspondingly increased and overflows (particularly those due to surges) are reduced. This latter influence of the OCO system appears to be the critical one in respect to stream pollution.

Some questions that arise regarding the contents of the paper are as follows:

1. Which waters are classified as high-solids and which as low-solids waters? The authors include some machine water in the low-solids system. They suggest the possibility of piping low-solids water directly to the pressure filters in a future installation. In this event, the advisability of maintaining felt shower water, suction box waters, and lubricating waters apart from machine water might be investigated. These relatively clear waters contain 0.5 to 1.5 lb. per 1,000 gal. of suspended material, on the average, and could probably be piped directly to the pressure filters without decreasing filtration rates. The latter are affected more by slimes, fines, and pseudo-colloidal solids, with which these clearer waters become contaminated in the presettler system.

2. What is the nature of the "slime measuring units" indicated in the paper? There is much interest in practical methods for the measurement of slime growth. In a recent National Council for Stream Improvement study of factors affecting the re-use of board mill white waters and clarifier underflows, a laboratory hand sheet machine was constructed to measure slime development. This machine measured the rate of drainage of recirculated white water mixtures. The drainage rate was taken as an index of slime formation, inasmuch as these factors have an inverse relationship. This study indicated that slime formation is favored by the build-up of dissolved and colloidal matter and "fines"; however, the latter, *per se*, were not responsible for decreasing freeness. Slime growth in the presence of high concentrations of dissolved and finely divided suspended material was effectively controlled by bactericides. Control of pH in the range from 4.0 to 4.5 and temperature in the range of 100° to 122° F. was also effective in controlling slime growth.

3. The authors indicate the possibility of completely recovering all suspended solids and discharging only filtered water. Water balance data to support this suggestion should be included.

Adaptation of the OCO system seemingly depends on a detailed economic study. Installation and operating costs must be balanced against the benefits derived. Some of the questions which must be answered in regard to possible benefits are:

1. Is fresh water supply a problem?
2. What is the extent of the stream pollution problem?
3. Would filtered water improve the quality of the product?
4. What is the value of the recovered water and heat?
5. Would conversion to low-volume showers necessitate pretreatment of water, particularly in hard-water re-

gions? That is, would scale due to hardness and iron clog high-pressure shower nozzles?

In the employment of any system as involved as the OCO, success will depend to a very great degree on both sound design and careful operation. A very important design factor is adequate surge tank capacity, both preceding and following the filters. Considerable excess filter capacity over that required under ideal operating conditions should also be allowed. Clarifier capacity must be adequate to insure sufficient solids reduction for efficient filter operation. Careful operation is obviously indicated by the number of operations involved. Alum filter aid, chlorine, and other bactericides must be fed to the system. Clarifier operation must be carefully controlled; the filtration units require observation, as well as periodic servicing; and coordination with mill operation must be maintained.

The primary and all-important step in the solution of any stream pollution problem is reduction in waste water volume, if at all possible. The OCO system accomplishes this initial objective. It is hoped that it will prove to be an economically feasible process.

EFFECTS OF INDUSTRIAL WASTES ON MUNICIPAL SEWAGE WORKS AT DETROIT *

By Isadore Nusbaum

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The literature is replete with references to sewage treatment plants and sewer systems whose normal processes and structures have been seriously affected by industrial wastes. These references are not limited to the smaller municipalities, for serious losses in efficiency and effectiveness have resulted in even the largest plants. The present trend toward control of stream pollution by industry is not limited to industry which discharges directly to a receiving water, but has reached out to take in the processing wastes entering municipal sewers. In general, the responsibility for the control of industrial wastes in a municipal sewer system belongs to the community concerned and the municipality is held responsible for damage resulting from the release of deleterious wastes through the city sewers into the surface or ground waters. However, the Michigan Stream Control Commission (now the Michigan Water Resources Commission) attempted to enact a pollution standard and restriction on cyanide-bearing waste which authorized the Commission to establish standards and inspect establishments discharging cyanide-bearing wastes into the sewers located within the boundaries of a city sewerage system. The above legislation resulted from several large-scale fish killings, which were caused by large amounts of cyanide-bearing wastes released through city sewers, as well as directly into the surface waters. The same Commission has issued an order to a chemical manufacturer, located in a city disposing of its sewage into the Detroit system, whose wastes contain large amounts of phenols, to reduce the concentration of such wastes. It was found that tastes and odors in the water supply of a municipality downstream from the storm outlet containing the phenolic waste occurred following periods of storm-water discharge.

Thus, many municipalities and sanitary districts are found to be passing or defining sewer use ordinances limiting or prohibiting the discharge of industrial wastes into municipal sewerage systems. These regulations invariably have provisions prohibiting the release of substances which will cause destruction or obstruction of the sewers, physical damage to sewage works structures, toxic or obnoxious conditions in or around sewers or sewage treatment plants, and interference with sewage treatment processes.

Some municipalities have placed surcharges on the sewage disposal rates paid by industry, which are based on the increase in the strength of the sewage by the industrial waste. In the case of large cities, with either combined or separate sewer systems, it is believed that there is little justification for such increased rates where the flow from a varied industrial population constitutes approximately 50 per cent or less of the total sewage contributed to the system. This is particularly so in the districts in which the cost of sewage treatment is apportioned on the basis of the volume of water consumed or discharged into the sewers. It is noted in the manual on municipal sewer ordinances recently issued by

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the Federation of Sewage Works Associations (1) that scant attention is paid to the matter of special charges for industrial wastes. Indeed, much more emphasis is placed, both in the discussion in the manual and the model ordinance, on the production, where necessary, of a waste which will not interfere with normal operation of the sewerage system. Symons and Crane (2) have pointed out that in many cases where a strong waste is produced the quantity to be discharged into a large system is too small to have any effect on the treatment works when diluted and that the cost of making such charges frequently exceeds the benefits derived.

The aim of adequate control of the industrial wastes received by municipal systems should be to produce a sewage which can be handled and treated without special consideration. In the large system there are relatively few wastes which are of such nature that they must be excluded or require extensive pretreatment. An examination of data published by several sources (3)(4)(5) indicates that the mean composition of sewage from the large communities is comparable and on an average reflects no characteristics which create unusual treatment problems. This alone denotes that, for wastes which in small quantities or great dilution create no difficulties, controlled dilution into the municipal system becomes a satisfactory answer to the disposal problem. It is noted, also, that dilution of the sewage as shown by per capita consumption or discharge of water is an important factor in the strength of the sewage.

In industrial waste disposal into the sewers of a large municipality, or for that matter any municipality, it must be recognized that the sewers themselves become an integral part of the treatment works, rather than merely a means of conveyance. The effect of the mixing of many wastes in general produces a waste more amenable to treatment. Where there are long lengths of well-designed and ventilated sewers, oxygen absorption at the air-water interface may be quite important in the resulting strength of the sewage.

TABLE I.—Annual Average Chlorine Demand of Detroit, Mich., Sewage Treatment Plant Influent

Year	Chlorine Demand (p.p.m.)
1942-1943	5.63
1943-1944	7.85
1944-1945	6.18
1945-1946	7.77
1946-1947	6.67
1947-1948	6.18
1948-1949	6.31

An example of "sewer treatment" of an industrial waste is found in the data on chlorine demands (Table I) accumulated from the records of the Detroit sewage treatment plant. The daily discharge of untreated steel pickling liquor into the Detroit sewers prior to the present program of industrial waste control was sufficient to have increased the average chlorine demand at the plant by 15 to 20 p.p.m., exclusive of other high chlorine demand wastes. However, Table I shows that the range of average annual chlorine demands was from 5.63 to 7.85 p.p.m. prior to the institution of any major controls. These averages and the accompanying monthly averages from which they were made are well within the limits prescribed for raw sewage (6 to 12 p.p.m.) by Enslow (6) and for domestic sewage (5 to 15 p.p.m.) by Symons (7). However, the periodic peak chlorine demands, which do occur, exceeding the chlorination capacity of the Detroit plant temporarily, plus the effect of the acid on concrete and brick sewer structures, require the exclusion of this particular untreated waste from the system.

Laboon (8) states in a discussion of the industrial waste problem at Pittsburgh that within the limitations estab-

lished for certain toxic and deleterious wastes all industrial wastes originating in the area to be serviced would be acceptable except pickle liquor wastes and acid mine drainage. The limits referred to by Laboon are concentration limits for toxic and deleterious wastes in the composite sewage to be treated.

Acid Wastes

Probably the one type of waste which has created more difficulties in the municipal system than any other has been the acid wastes. These wastes are not only notorious for their destructive action on the structures involved, but also are detrimental to almost every kind of sewage treatment process in general use. The principal acid wastes which must be handled by a municipal sewer system are the following:

1. Steel pickling wastes.
2. Acid electroplating wastes.
3. Copper and brass pickling wastes.
4. Acid wastes from the manufacture of acid.
5. Organic acid wastes, such as those resulting from the manufacture of pharmaceuticals, organic chemicals, and food processing.
6. Acid wastes from the graphic arts.
7. Rustproofing wastes.
8. Miscellaneous chemical and other manufacturing wastes (that is, from refineries, safety glass processing, acid etching, etc.).

In the Detroit system, for example, all the enumerated acid wastes may be found, plus many others. The acid waste problem may be divided, for the purposes of effect on the system and methods of treatment, into two general classifications. The first group includes those which are constantly acidic in nature, such as the continuous discharge of acid rinses from steel pickling or electroplating or the waste from a continuous manufacturing process. The second group comprises relatively concentrated acid wastes discharged intermittently in fairly large amounts, such as waste steel pickling liquor. It may be seen that many of the acid waste producing industries have the dual problem of intermittent and continuous disposal, which cannot necessarily be met by the same means.

Continuous acid wastes are generally low in concentration and, as a rule, present little or no problem as far as the treatment works is concerned. Their effect is local and usually limited to the destruction of sewer structures in the vicinity of the point of discharge prior to mixing with sewage containing sufficient amounts of alkalinity to neutralize the acid. Exceptions to the rule are always of interest; in the case of one large independent steel pickling company in Detroit, acid damage requiring repairs was noted up to one mile from the source.

It has been observed in Detroit that a relatively small amount of structural damage has been found where the discharge of acid is infrequent, but that the greatest damage has been located where there are both intermittent and continuous discharges. Treatment of the low concentration continuous acid discharge is a simple problem, but not necessarily an inexpensive one, depending on the volume of wastes to be treated. Lime slurry, soda ash, caustic soda, or strong alkaline wastes may be fed to the acids within the premises to produce a neutral effluent. It may or may not be necessary to provide additional agitation. The turbulence of flow found in the plant sewer will usually provide sufficient mixing. Wastes thus neutralized may be controlled to the lower end of allowable pH limits in the interests of economy, as the prime function here is to prevent acid damage. It is sometimes necessary to limit the neutralizing agent which may be utilized. The chlorine breakpoint in a raw-water supply is dependent on the ammonia

nitrogen concentration. Variations and increases in the ammonia nitrogen of an effluent discharged above the water supply of a community practicing breakpoint chlorination may cause serious interference with water chlorination control. An acid manufacturer in the area who wished to utilize liquid ammonia to neutralize his waste was denied the privilege, because it was felt that other economical neutralizing agents were available which would not add to the ammonia nitrogen problem.

The problem of continuous acid waste disposal may be further controlled or eliminated by a survey of the process producing the waste and its relation to the plant. In a large plant possessing several outlets, for example, it may be possible to divert the waste to another outlet to utilize available alkalinity present and neutralize the acid.

In many industries where the dual problem of continuous and intermittent acid wastes exists, the strong periodic wastes may be retained and diluted slowly into the continuous flow, creating a single waste of uniform concentration which may be handled with a minimum of equipment and expense. It should be pointed out that it is a mistake on the part of any industry to assume without additional tests that the mere presence of alkaline wastes as well as acid wastes in the plant effluent constitutes sufficient treatment. The belief of a portion of the electroplating industry that pulling the plug on the alkaline cleaners at the same time that the acid dips are discharged, and that overflowing alkaline rinses at the same time as acid rinses, answers the waste treatment problem is not satisfactory. This belief is not supported by those engaged in industrial waste control.

Steel pickling wastes form almost a problem of their own in any treatment works, but are particularly disastrous in a primary plant using chlorination for disinfection. The chlorine dosages required following the discharge of large amounts of pickling acid may become astronomical in value and the effectiveness of the plant in destroying bacteria becomes practically nil. Although Detroit is not a major steel producing center, it is a major steel fabricating center and large amounts of waste pickling liquor are discharged into the city sewers at many points. Interference with chlorination has occurred up to about 20 per cent of the operating time. It was found that to reduce the chlorine demand of the waste to a negligible value it would be necessary to neutralize the liquor to pH 7.5 to 8.0 with a detention period of approximately one hour, using strong alkaline agents such as lime, soda ash, or caustic soda.

As has been shown by many observers, and particularly by Hoak and his associates at the Mellon Institute, the resulting slurry is slow in settling and does not respond readily to commonly used means of separation. This provided a serious problem to industry, as in a densely populated industrial center such as Detroit, the space necessary to provide adequate treatment was not available. It was found that, in most cases, the industries doing the steel pickling used large amounts of water, which was available for dilution, and were so located with respect to the sewer system that conditions of flow in the sewers were generally good. It was decided to permit the discharge of the diluted neutralized pickling liquor, containing the precipitated solids, into the sewers when the suspended solids in the plant effluent could be kept in the neighborhood of the maximum temporary limit (10,000 p.p.m.) permitted in the Detroit standards and regulations (9) controlling the discharge of industrial wastes into the sewer system. The solids are readily removable in the primary sedimentation tanks of the Detroit treatment works.

So far, no increase in the suspended

solids in the sewage plant influent has been observed which might be traceable to the neutralized pickle liquor. In addition, the presence of pickle liquor in Detroit sewage has not been without benefit, as several analyses indicated dissolved ferrous ion concentrations of about 500 p.p.m. in the raw sludge of approximately 9 per cent dry solids. The presence of this ferrous ion has probably been a factor in the low ferric chloride requirement for sludge conditioning reported by the Detroit treatment works.

Chromic acid wastes, copper and brass pickling wastes, and other discharges of similar nature present a problem by virtue of the toxicity of the metals for the organisms in sewage processes involving bacterial action. To date these wastes have been treated merely by neutralization in the Detroit system. The only biological process in the Detroit treatment plant is the digestion of a portion of the raw sludge produced and not a great deal of work has as yet been done in Detroit on the interference of these metals with sludge digestion. Several instances have been reported in the literature of interference by copper, but these have involved concentrations as high as 3,000 p.p.m. in the digested sludge. There is little evidence to indicate such a build-up in a large urban district. Despite the fact that large amounts of concentrated chromic acid solutions have been known to be wasted into the sewers, there have been no instances of recognition of these wastes in the Detroit plant influent as was reported in New York. It is believed that the amounts of chromic acid normally discharged in rinse waters, in even as large an electroplating and metal treating center as Detroit, are readily reduced in the dilute sewage of a large municipality; therefore, it has been recommended to industry that should it be necessary to waste concentrated solutions of chromic acid (an expensive procedure at best) they be diluted into the normal processing discharge at a low rate.

In recapitulation, it may be stated that neutralized acid wastes can be discharged, with the precipitated solids formed on neutralization, into the sewerage system of a large municipality or sanitary district with little fear of ensuing difficulties. However, it should be emphasized that in Detroit permission granted to waste acid processed in the above manner has not relieved the particular industry of the responsibility for a blockage should it occur.

Inflammable and Explosive Wastes

Inflammable and explosive wastes must be excluded from a municipal system. As they usually represent the loss of a valuable product through the development of leaks or accidents, the correction of this waste problem is not delayed. The most frequent occurrences are from leaks at bulk storage and gasoline stations and accidents involving trucks transporting the inflammable substances.

High Solids Wastes

Wastes causing obstructions in sewers must be excluded without exception, unless treated prior to release into the sewers. These wastes will include those from auto laundries, industrial laundries, rug pad manufacturers, rendering plants, packing houses, asphalt processing plants, and many others. On the other hand, sewage from industries that are generally considered troublesome (such as breweries, slaughter and packing houses producing paunch manure, etc.) may be discharged into the large municipal system with only a coarse screening, provided the waste is diluted sufficiently.

Wastes high in organic suspended, colloidal, and dissolved solids (such as brewery waste, wastes containing paunch manure, milk processing wastes, anti-biotic wastes, canning

wastes, and ground garbage), when diluted into the large municipal system, quickly lose their identity and are readily treated. There is, indeed, little justification for the requirement of special treatment for laundry and food processing wastes, among others, in the large municipal sewerage system where obnoxious effects are not created locally, especially when the daily load from domestic installations may exceed the industrial load by far and the industrial waste actually represents a substitution for much of the domestic waste.

Grease, Oil, and Tar

Grease, oil, and tarry substances must be removed down to a reasonable limit before entering the city sewers. These wastes are most effectively handled by preventing the substance from coming in contact with water in the first place. Mineral oils present little problem as far as the sewers are concerned, but cause many difficulties in treatment plant operation. They are prone to pass through primary plants without removal, thus causing an unslightly stream pollution problem. Also they are almost impossible to digest and interfere with most biological methods of treatment. A concerted educational program—by industry—directed towards the employee, plus the inclusion of devices on machinery and processes to prevent oil losses, should do much in relieving this nuisance.

Cyanide Wastes

Because of the previously mentioned effort on the part of the Michigan Stream Control Commission to regulate cyanides discharged into municipal treatment systems, as well as directly to receiving waters, a study was made of the concentration of cyanides in the influent to the Detroit sewage treatment plant. There is located in Detroit probably the greatest concentration of the electroplating industry in the world, representing a huge source of cyanide wasted into the sewers. In addition, cyanide baths used by steel picklers to recolor the metal are discharged at frequent intervals and cyanide wastes are in some cases permitted to enter the sewers from steel treating establishments.

A total of 51 daily composite samples of Detroit treatment works influent was analyzed for cyanide using the method in "Standard Methods" (10). The maximum concentration found was 0.22 p.p.m. as cyanide; the average was less than 0.1 p.p.m. For a period of 14 days, hourly qualitative tests were made on the influent using the phenolphthalin method (11). The test is reported to be sensitive to 0.4 p.p.m. cyanide and is likely to give high results. Of the 336 samples tested, none gave a positive test for cyanide. It is quite evident that changes occurring in the sewers other than those due to mere dilution are producing lowered cyanide concentrations at the sewage treatment plant. Based on the above data, it was determined to control cyanide concentrations from the standpoint of preventing toxic atmospheres in and around sewers. In a paper published in England (12) the conclusion was reached, following extensive research work on the release of HCN from sewage to the atmosphere, that in large sewers in which men may have to work for periods of several hours the concentration of cyanide as HCN in the sewage should not exceed 10 p.p.m. (approx. 10 p.p.m. cyanide) and in small sewers should not exceed 20 p.p.m. (approx. 20 p.p.m. cyanide). It appears obvious that wastes containing small amounts of cyanide should be acceptable in the large sewer system without pretreatment. Where quantities of waste containing high cyanide concentrations, such as copper or zinc cyanide plating solution, which must be disposed of, are to be discharged, these may be diluted into the sewer at a low

rate, in that way preventing high concentrations of HCN from developing in the sewers and precluding the possibility of shock loads at the treatment works. Nevertheless, the use of the alkaline chlorination treatment for cyanides is recommended for industry contributing to the municipal system where a large quantity of concentrated cyanide must be disposed of rapidly. Furthermore, some means of separation of the cyanide wastes in the plant is preferred, as only in this manner can accidental spillages be controlled.

Phenolic Wastes

Theriault (13) in 1929 reported that domestic sewage contained up to 500 p.p.b. of phenolic substances. These data have been used by some factions to dispute the belief that most of the pollution from phenols is due to industrial wastes. Unpublished data (14) by the U.S.P.H.S. indicate concentrations of phenols in domestic sewage of less than 20 p.p.b. There is some doubt as to the generality of the conclusions, as there was a considerable variation in the limited number of grab samples analyzed. As a part of the International Joint Commission investigation of pollution in the Detroit River, the U.S.P.H.S. made a study of concentrations of phenolic materials found in the influent and effluent of the Detroit sewage treatment plant. During a period of low industrial activity phenols determined in the Detroit influent averaged about 70 p.p.b. The reduction in phenolic substances through the Detroit plant (primary treatment plus chlorination) was negligible.

The U.S.P.H.S. has published a paper (15) demonstrating that the reduction in phenols in natural waters is the result of microbiological action and that the presence of small amounts of bacterial pollution increase the rate at which the phenols are removed. It is quite possible that significant reductions in phenol concentrations may take place in the sewers of a large metropolitan area. This possibility and additional information on the concentrations of phenolic substances in Detroit sewage are now being investigated. No suitable means for reducing phenols to a satisfactory level in the effluent from an industry located on a municipal sewer system has yet been devised except re-using the wastes containing these substances in the processing. Some promise is now held out to industry by the recently announced research in progress on the use of chlorine in treating phenolic wastes.

Soluble Oil Wastes

The "soluble oil" problem is one which must be considered separately from the ordinary oil or grease disposal problem. In Pittsburgh, for example, where it has been recommended that mineral oils be excluded from the sewers, the limits require only maximum practicable removal of oil before discharge of the soluble oil emulsion to the sewers (16). Some work has been done in Detroit in attempting to determine the presence of the soluble oils in the influent of the Detroit treatment plant following the discharge of large quantities of these materials into the sewers within two miles of the treatment works. Little direct evidence of the presence of excess emulsion or oil was found. This has led to the theory that the emulsion is readily cracked in the sewers or that on dilution the emulsified oil is adsorbed by other sewage solids present. Additional work is continuing on these materials. It has been considered that a great deal of the phenols present in Detroit sewage from industrial discharges may be due to preservatives used in some of the oil emulsions. At present, industry should be required to remove all readily separable oil and the remaining emulsion should be discharged at a low rate into the municipal sewers.

Summary and Conclusions

The many difficulties caused by industrial wastes which are frequently encountered by small sewerage systems are not commonly found in large municipal systems. The principal sources of difficulty in the large system may generally be attributed to intermittent discharge of a relatively few wastes. It is essential to pretreat these wastes before they enter the sewers. Where the population equivalent of the industrial wastes in the sewers is less than or does not appreciably exceed the domestic load, little interference with treatment works operation is to be expected. The use of dilution as a method of treatment of industrial wastes in the large city sewage treatment system is valid and the sewers themselves should be considered as more than a means of conveying the sewage to a point of disposal.

References

1. "Municipal Sewer Ordinances." Manual of Practice No. 3, FSWA (1949).
2. Symons, G. E., and Crane, F. W., "Special Sewer Charges for Industrial Wastes." *Water and Sewage Works*, **91**, 6, R-166 (1944).
3. Keefer, C. E., "Sewage Treatment Works," Chapter 5. McGraw-Hill Book Co. (1940).
4. Metcalf, L., and Eddy, H. P., "American Sewerage Practice," Vol. 3, Chapter 5. McGraw-Hill Book Co. (1935).
5. Babbitt, H. E., "Sewerage and Sewage Treatment," Chapter 15. 6th Ed. John Wiley and Sons (1947).
6. Enslow, L. H., "Chlorination in Sewage Treatment Practice"; Chapter 8, "Modern Sewage Disposal." FSWA (1938).
7. Symons, G. E., Terhoeven, G. E., and Torrey, W. L., "Laboratory and Field Studies on Chlorine Demand of Sewage." *Water Works and Sewerage*, **85**, 8, 789 (1938).
8. Laboon, J. F., "Industrial Wastes Disposal at Pittsburgh." THIS JOURNAL, **22**, 4, 549 (Apr., 1950).
9. Palmer, C. L., "Control of Sewer Usage at Detroit, Mich." *Sewage Works Jour.*, **18**, 6, 1127 (Nov., 1946).
10. "Standard Methods for the Examination of Water and Sewage," p. 90. 9th Ed. Amer. Pub. Health Assn. (1946).
11. Theroux, F. R., Eldridge, E. F., and Mallman, W. L., "Laboratory Manual for Chemical and Bacterial Analysis of Water and Sewage." 3rd Ed. McGraw-Hill Book Co. (1943).
12. Lockett, W. T., and Griffiths, J., "Cyanides in Trade Effluents and Their Effect on the Bacterial Purification of Sewage." Paper presented at the Public Works, Roads and Transport Congress, England (July 25, 1947).
13. Theriault, E. J., "Chemical Aspects of Stream Pollution by Phenols." *Ind. Eng. Chem.*, **21**, 343 (1929).
14. Ettinger, M. B., "Phenol Content of Domestic Sewage." Unpublished.
15. Ettinger, M. B., and Ruchhoft, C. C., "Removal of Phenols and Cresols from Natural Waters." *Ind. Eng. Chem.*, **41**, 7, 1422 (1949).
16. Laboon, J. F., "Sewage Disposal Program of the Allegheny County Sanitary Authority." *Sewage Works Jour.*, **21**, 2, 197 (Mar., 1949).

MICHIGAN'S INDUSTRIAL WASTES CONTROL PROGRAM *

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Industrial waste disposal is a subject that is receiving greater attention today than ever before. Interest in this problem has perhaps been intensified by the realization of the public that unless pollution is arrested and corrected, the value of our water resources would ultimately be destroyed. The resulting demand for more stringent laws and greater accomplishment towards the goal of clean waters has not been without foundation. A great deal of publicity given to certain so-called "running sores of our land" has produced public demands for correction of existing problems and protection from any new sources of detrimental pollution.

An important factor in bringing industrial waste disposal into prominence has been the increase in wastes caused by industrial expansion and the production of new types of wastes from the manufacture of new products. The public health aspects of pollution have been supplemented correspondingly with other interests, such as wild life, recreation, sport and commercial fishing, and agriculture, just to mention a few. Because industrial wastes are of such a nature as to affect these interests more directly, the result has been an increasing number of state laws containing provisions applying specifically to industrial wastes.

Broader Protection of Waters

Where earlier laws were directed primarily toward control of pollution injurious to public health, authority is now being extended to protect a much wider category of water uses and to place greater emphasis on injuries directly related to industrial waste pollution. The enactment last year of amendments to the Michigan law is an example.

Prior to 1949, control of water pollution was vested in the Stream Control Commission, composed of five members who held membership by virtue of their positions as state officials. They were the Commissioners of Health, Conservation, Agriculture, and Highways, and the State Attorney General. Most of the interests vitally affected by pollution injuries were joined and coordinated by this statute.

Much was accomplished during the 20 years this law was in effect. The penalty provisions were seldom utilized, but legal actions were taken and courts in all cases upheld the law and actions taken by the Commission under it. However, as industrial expansion and population increases came about, inadequacies began to appear in the law. Increasing public pressure arose for more rapid corrections and for a stronger authority to deal with the pollution problems throughout the state. It became increasingly evident that other phases of the state's water problem required attention, particularly some overlying agency to administer water resources generally.

New Agency

In 1949 the 1929 act was amended and enacted in the form of the present law. This law created a new agency supplanting the Stream Control Commission, with broadened powers to cope

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with increasing pollution problems, and in addition delegated certain duties with respect to flood control, beach erosion, and underground water protection. Its duties are, in general, to protect and conserve the water resources of the state, to control and prohibit the pollution of any waters of the state and the Great Lakes, and to cooperate and negotiate with other governments and agencies in matters concerning the water resources of the state. The membership of the commission was increased to seven and the name changed to the Water Resources Commission.

The new commission is composed of the Commissioners of Health, Conservation, Highway, and Agriculture, and three citizens of the state appointed by the Governor to represent industrial management, municipalities, and conservation associations or interests.

The scope of the Commission's authority is defined as extending over all surface and underground waters of the state and the Great Lakes, which may be affected by wastes disposed from municipalities, industries, public or private corporations, individuals, partnership associations, or any other entity. The specific inclusion of underground waters represents an important addition to the authority granted by the earlier law. The importance of the control of underground pollution will be noted when one considers that 74 per cent of the water supplies in the state are obtained from underground sources.

A test of the commission's authority to control underground water pollution is in progress in a current court case. The decision rendered in this case will be of utmost importance in the protection of the underground water resources of the state.

The section of the law that defines unlawful pollution provides the basis upon which the Commission may act. It is of greatest significance to any industry now producing or planning to produce any wastes which may be disposed of to state waters. The law sets the pattern for all users of the state's waters to follow in disposing of wastes. It is interesting and significant to note that pollution injurious to the conducting of any industrial enterprise is included. Thus, this water use is recognized along with others that need to be protected and places industry in a position to press for relief against other polluters.

Prior Approval Now Required

The section on new or increased pollution of the waters of the state remedies a deficiency which materially hampered the pollution abatement efforts of the Stream Control Commission. Prior to the date of enactment of the present act, it was extremely difficult to require protective measures to be taken prior to the time a new industry began operations. Industries that were known to be producers of polluting waste materials could become established and start to create pollution problems before action could be required. This resulted in many acute problems and frequently caused expense, which might have been avoided had the necessity for control been recognized during the planning and construction period.

This unsatisfactory situation to both the potential polluter and the Commission has been remedied by making it the duty of any person requiring a new or substantial increase over and above the present use now made of the waters of the state for sewage or waste disposal purposes to file with the Commission a written statement setting forth the nature of the enterprise or development contemplated. The statement must include the amount of water required to be used, its source, and the proposed point of discharge of the wastes into the waters of the state. Information as to the expected bacterial, physical, chemical, and other known characteristics of the wastes is also re-

quired. Within 60 days of receipt of the written statement, the commission is required to make an order setting the restrictions which in its judgment are necessary to guard against such unlawful uses as are defined in the act.

Industrial Status Reports

One very effective instrument leading towards adequate treatment of industrial wastes and protection of the state's waterways has been the issuance of Industrial Status Reports by the Commission. The first such report was issued on March 15, 1948, the second on May 15, 1949; the third will be issued in 1950. Publication of these listings in newspapers and magazines throughout the state has prompted industrialists to strive to improve the ratings of their plants for public relation purposes. Public opinion is serving as one of the best agents in cleaning up and protecting streams.

The Industrial Status Report is a compilation of industries discharging either sanitary sewage, or industrial wastes, or both, into a watercourse and giving these plants a rating corresponding to the adequacy of control provided over their waste discharge, as follows:

Class	Wastes Control
I	Control adequate
II	Control provided; adequacy undetermined
III	Control facilities available; protection found unreliable
IV	Municipal treatment facilities utilized; industrial overload
V	Studies, plans, or construction underway
VI	Existing control inadequate or incomplete
VII	No control
VIII	Need for control undetermined

Industrial plants listed in Class I are those that in the opinion of the staff and Commission provide and maintain control measures or treatment adequate for protection of the receiving waters against damages from pollution.

Those in Class II provide the control measures or treatment necessary for protection of the receiving waters, but have not had the units in operation long enough to determine their adequacy.

Class III plants are those having control facilities available, but because of poor maintenance or operation have been found unreliable for protection of the receiving waters.

Plants utilizing municipal facilities for waste disposal are listed in Class IV if their wastes are considered to be overloading the municipal facilities. If the municipal facilities are operating adequately, plants connected to the sewer system are not listed.

Industries listed in Class V are those whose waste treatment units or control measures are still in the study or planning stage, or who have units under construction.

Class VI is provided for plants whose control measures are either incomplete or provide inadequate control over industrial wastes or sewage discharged from the plant.

Industries listed in Class VII are those that provide no control over the wastes they discharge to the watercourse.

Those listed in Class VIII discharge wastes for which the need for control is undetermined.

It may be interesting to note that during the 13-month interval between the publication of the first and second status reports, industries listed in Class I increased by 40 per cent and in Class II increased by some 120 per cent.

Example of Progress

The matter of cooperation between industry and the Commission may well be exemplified by a brief summary of the progress made in the beet sugar industry.

Prior to 1939, fish killings below sugar plants were quite prevalent. The treatment of flume water, battery

wash, and pulp press water consisted of coarse screening followed by plain settling in large storage ponds. Separate ponds were provided for lime slurry to permit recovery of dried cake for agricultural usage. Steffens process wastes were impounded during the beet season and released during the high-water stages in spring.

The failure of these methods of disposal to provide adequate stream protection led to the inauguration of an experimental program designed to provide more efficient treatment. In 1935, a pilot plant, financed by the Farmers and Manufacturers Beet Sugar Association, was operated at Bay City in cooperation with the Engineering Experiment Station of Michigan State College. The results of these experiments were the basis for the construction in 1936 of one unit of a full-scale plant to treat 1 m.g.d. of factory wastes. Operation of this unit in 1936, 1937, and 1938 was followed in 1939 by construction of a full-scale plant for handling in excess of 5 m.g.d. of wastes. This plant consisted of a drum-type screen for removal of coarse solids, a grit chamber equipped with continuous grit removal mechanism, a coagulation tank, and clarifiers equipped for continuous sludge removal. Lagoons were provided for disposal of sludge.

The development and operation of a practical method of treatment within reasonable economic limits was followed, in 1937, by the adoption of a general order by the Stream Control Commission. Under the terms of the order the discharge of Steffens wastes, either independently or in combination with other wastes was expressly prohibited after October 1, 1940, and other factory wastes were restricted in polluting content to not more than 5 lb. of 5-day B.O.D. per ton of beets processed after October 1, 1939.

All of the beet sugar plants in Michigan are striving to meet the standards adopted by the Commission. Various methods of treatment were inaugurated to comply with this limit. Basically, these waste treatment systems provide for segregation of clear water, with various degrees of recirculation and re-use of process waters, and use of impounding reservoirs. Flume water is now generally passed over a shaker screen for removal of beet toppings and tails, and then through a grit chamber for removal of heavy suspended solids. The effluent from the grit chamber is recirculated for flume water with fresh water or clarifier effluent for make-up.

In several plants process water is passed through a flocculator and clarifier, with the effluent used in part for flume water make-up and the balance discharged to the receiving waters. One plant, having the available land acreage, uses a series of ponds; a final pond is used as a sand filter with tile underdrains draining to the river. Although these systems have been only moderately successful, their failures have been due to operational or mechanical difficulties, not to unsoundness of the fundamental principles of design. Six of the ten plants in operations in 1949 showed a B.O.D. of less than 4 lb. per ton of beets processed—well under the allowable limit.

Proper Operation Essential

It should be emphasized that the pollution problem does not end with the installation of waste treatment facilities. The full benefits of the corrective measures will not be realized unless equipment and processes are properly operated and maintained. Each new installation presents a continuing job for the staff of the regulatory agency to see that treatment performance is kept at a satisfactory level and that the facilities are not neglected.

Although there are severe obstacles blocking the way to immediate solution on many problems, control of pollution by industrial wastes is advancing and much is being accomplished.

There is increasing evidence that industry is more responsive to public demand for pollution abatement. Companies are coming to recognize the value of a good waste disposal record in maintaining good public relations and are accepting their obligations. They are establishing industrial waste committees within their organizations to study and keep abreast of waste treatment developments.

In conclusion it should be stressed that it is industry's duty, as well as that of the state's protective agencies, to protect and promote the water resources of Michigan.

TEXAS INDUSTRIAL WASTE SYMPOSIUM

The Second Annual Industrial Waste and Stream Pollution Symposium was held at Houston, Tex., on October 13, 1950, in conjunction with the Annual Gulf Coast Regional Conference on Industrial Health. The success of the meeting is indicated by the registration of some 400 persons, more than 200 of whom were in attendance at the symposium session. The meeting was sponsored jointly by state and county health departments, the Texas Manufacturers' Association, and other allied agencies and associations.

Among the interesting subjects discussed at the meeting were the present trends in industrial wastes control and state legislation in the United States, what industry expects from state regulatory bodies in the controlling of industrial wastes, and the model stream pollution law promulgated by the Public Health Service.

Speakers at the Industrial Waste Luncheon were representatives of the several research and engineering experiment stations in Texas, who outlined the facilities available at their various institutions and invited consultation on special problems of industry requiring personnel and equipment beyond the scope of the particular industry involved.

Stream Pollution

GROUND-WATER POLLUTION IN MICHIGAN *

By Norman Billings

Hydrogeologist, Geological Survey Division, Department of Conservation

During recent years, a great deal of public attention has been focused upon the polluted condition of streams and widespread demands for the reduction of that pollution have given rise to a very active program of corrective projects. It is beyond the scope of this paper to consider all the pros and cons of this development, but it is of interest from the standpoint of ground water because of the implications it raises. If certain wastes are not permitted to be put in the streams, where can they be disposed? The only answer, in many cases, has been to put them on the ground. For some wastes this is undoubtedly preferable and even desirable. For others, however, it is very undesirable and sometimes highly dangerous because of the possibility of polluting ground waters.

Formerly, it generally was felt that the passage of contaminated water through porous sands and gravels would purify it. This assumption is supported by the obvious fact that rain and snow water must surely become highly contaminated with bacteria and the products of organic decomposition when it touches the soil surface, yet when it reappears in wells and springs it is pure and clean. However, it has been found that this purifying action, which apparently involves factors of filtration, temperature reduction, and oxidation, has its limitations. Waters carrying certain offensive tasting, poisonous, or otherwise undesirable materials (such as some creosote-type compounds, chromates, picric acid, and common table salt) seem to find their way into the ground-water reservoirs without becoming purified. It is probably true, also, that many other undesirable substances are not filtered out.

Opportunity for Penetration

These waters undoubtedly follow the same pathway as rainwaters in their entrance into the ground-water reservoirs and have the same opportunity as rain or snow to penetrate the ground. The extent of this opportunity varies considerably from place to place, depending on the local geology. In the more porous geological formations, such as the outwash plains, practically all the rain and snow melt enters the ground, but all of it does not become available for ground-water reservoir replenishment because large percentages are intercepted and transpired by plants. On the other hand, in the heavy clay formations, such as in the old lake beds, ground-water recharge is very limited.

A fairly reliable index of local recharge is the drouth-time flow of streams. In using this index caution is necessary because ground water drainage basins do not necessarily coincide with surface water drainage basins, and because evapo-transpiration losses may obscure the true base flow. Where the streams tend to dry up or to diminish very considerably during dry weather, it may be assumed that they are supported largely by overland runoff rather than by ground-water runoff.

In all parts of Michigan, however,

* Presented at 1950 Annual Meeting, Michigan Sewage and Industrial Wastes Association; Traverse City, Mich.; May 22–24, 1950.

where observation of ground-water levels is in progress, the annual recovery of ground-water levels establishes beyond doubt that at least somewhere locally very significant amounts of rain and snow waters are able to reach the ground-water reservoirs. These are the reservoirs which have for ages past maintained the base flow of streams and which supply the well water for cities, industries, and homes. Water production from wells is automatically at the ultimate expense of base stream flow.

Slow Movement

The fact is established that waters contaminated with undesirable wastes can and do enter the ground waters under favorable geological conditions. Questions relating to their subsequent movements, therefore, become very important. Will not such contamination become so diluted by the enormous volumes of water in the ground as to become undetectable or at least harmless? And will not the great quantities of natural recharge quickly flush the contaminated waters away, reducing the problem's duration to an inconsequential figure?

The apparent answers to these and other reasonably posed questions are discouraging. Certainly, some dilution does occur, but not to a satisfactory extent. The movement of ground waters is so painfully slow that contamination sometimes persists for years, and possibly decades, after its introduction.

At the village of Douglas, wastes from a plating plant were five years in reaching a city well only 1,000 ft. away, even with an artificial acceleration in flow caused by pumping the well. At Lansing, more than three years of pumping was needed to exhaust a picric acid contamination, which had entered the ground waters from a disposal sump about 500 ft. distant from the wells. This meant that more than a third of a billion gallons of water was pumped as waste at a cash cost of nearly $6,000, plus overhead. Phenolic contamination has appeared in city wells at Alma and in farm wells at Antrim. Salt has knocked out city wells at Lowell and Edmore. At other locations, gasoline, cheese factory wastes, and septic dry wells have ruined local ground waters, at least temporarily.

Flow Difficult to Predict

Water, being a physical substance, naturally follows the laws of nature in its movements underground as well as above ground. It always flows in the direction of greatest hydraulic gradient. However, ground-water slopes are so gentle and so well hidden under the ground that usually a pretty careful survey is necessary to find out in which direction the water is moving. The influence of high-capacity water wells, drainage ditches, local cloudbursts, dam construction, and other factors have pronounced effects on water levels and gradients so that water which has been slowly seeping in one direction may change course and speed many times before it eventually reaches a lake, stream, or well. Whether chromates dumped on the ground by plating plants will end up in the river or in the schoolhouse well depends on the details of local geology and hydrology, which are seldom so simple as to permit easy appraisal.

In the absence of reasonable indication about where potential contaminants are going to go when dumped on the ground, such disposal carries obvious hazards. Getting away with it safely for a period of years is no basis for complacency. Actual damage may go unnoticed, merely because the water was not being drawn upon by local wells or because contamination has not migrated far enough to enter areas from which water is used.

Major Considerations

The dangers associated with the disposal of waste onto or into the ground,

which it has been attempted to show, do not necessarily imply that all such dumping should be stopped. In determining the sensible way of handling any disposal problem several things ought to be considered.

First, how bad is the material to be gotten rid of, from the standpoint of the damage it can do? If it is a deadly poison, naturally, great care will need to be exercised in the interests of safety, regardless of other conditions. It might be best to prevent any of the seriously poisonous substances from getting on the ground at all until they have either been diluted to a safe degree or treated so that they are no longer poisonous.

Second, what chance does the waste have of getting into the ground? Where the soils are heavy clay of considerable thickness, it may be feasible to use surface pits for the storage of certain wastes pending occasional removal, provided adequate precautions against their escape are taken.

Third, what harm is the waste apt to do if it does reach the ground-water reservoirs? Simple chlorides, sulfates, carbonates, and other substances are already found in most ground waters. In some cases, such constituents can be increased to a reasonable degree without damage.

Fourth, where is the waste likely to go after it gets into the ground water? Will it move in the direction of wells or will it be carried directly to nearby streams and there dissipated? Under constant conditions of water table or water pressure surface slope the contaminated waters tend to remain in a relatively narrow belt between the source and the discharge point. Opportunities for diffusion seem to be poor and the movement of the contaminated water apparently is dictated largely by hydraulic head differentials.

It must be kept in mind that the influence of high-capacity wells often covers a large area and that all the ground waters within that area which are in hydraulic connection with the producing formation tend to move toward the wells. Where annual recharge by rain and snow amounts to 5 in. per year, a well which constantly pumps 500 g.p.m. requires 3 sq. mi. of drainage area to supply its needs. It may not be assumed, however, that these 3 sq. mi. comprise a circular area in which the well is centered. In many places the area of 3 sq. mi. may be a narrow strip that extends several miles, depending on the depth of the well, the continuity of clay or shale formations overlying the water-bearing formation, and local conditions of soil permeability.

It is possible to make investigations that provide the basis for good estimates of how local ground waters move. Such investigations are apt to be expensive, however, and no matter how detailed and exhaustive they may be the results will never be absolutely conclusive. The earth is ever changing and the science of geology is not and never can be exact, as compared with the mathematical sciences. The best that the geologist can do under many circumstances is to make a scientific estimate, the detailed accuracy of which depends on how much data is available to him. Where the geology is complex, as it is in the glacial drift covering Michigan, he is further handicapped. It is not too difficult to determine the nature and origin of the surface deposits. But when it is considered that the drift consists of materials laid down by at least two separate glaciers and that during its final phases the glacier frequently readvanced and reworked its earlier deposits, some appreciation can be gained of what the geologist is up against in unravelling the pattern of deep formations.

Pumping Tests Help

In recent years, newly developed pumping-test methods have done much to help in appraising the hydrology of ground-water reservoirs, but interpre-

tation of pumping-test results only refines the degree of accuracy of appraisal and can never eliminate all elements of uncertainty about what may occur in the future. Pumping tests do have great value, however, in the establishment of liability in cases of well contamination after contamination has occurred. In the past, the courts have been handicapped by the lack of proof in law suits over contamination. It is now feasible to determine beyond doubt whether an alleged source is or is not in hydraulic connection with a specific well and if the ground water is moving from the contaminating source toward the well.

Legal Restrictions

With growing public recognition of dependence on water resources, legislatures and judiciary are tending more and more to restrict the rights of individuals with respect to those resources. The precepts of the past, which pretty much allowed a person to do as he chose with his own property are becoming modified with the proviso that he may do so only so long as he does not endanger the welfare of his neighbors. In recently determining the constitutionality of a state law, which in effect abandoned the riparian law of waters and invoked the appropriation law, the Supreme Court of Kansas used the following language: "Individuals do not live alone in isolated areas where they, at their will, can assert all of their individual rights without regard to the effect upon others."

Restrictions dictated by recognition of the public welfare are by no means confiscatory, as the satisfactory operation of Michigan's oil and gas laws demonstrates. Born in the 1920's with the discovery and development of the Muskegon pool, the oil and gas industry started life as a squalling undisciplined brat, whose functioning was grossly inimical to agriculture and recreation and which posed an enormous threat to Michigan's fresh water and brine resources. It was quickly restricted and controlled by effective legislative measures, which were sponsored by a large part of the industry and which were designed not only to safeguard other interests but also to conserve the oil and gas.

In spite of its early vociferous protests, the fractious element of the industry found that the regulatory measures were not confiscatory and they have long since come to be accepted and generally welcomed by all. Today, Michigan's oil and gas industry is nationally—and that means internationally—looked up to as an example of how a potentially objectionable and wasteful industry can get along with other interests, conserve resources, and still compete in the world market. In order to meet legal requirements, the industry had to find and has found means for safely disposing of brines, which greatly exceed the volume of the oil produced. It has had to and does observe strict precautions, from the time the drilling rig is set up until the well is approved by the state as being safe for abandonment, in order to insure that its operations may not cause offense or damage to this or future generations.

Close Regulation Needed

In time to come it is fully expected that there will be enacted measures requiring other industries to assume the same degree of responsibility in conservation of resources that the oil and gas industry now accepts as a matter of course. This responsibility, naturally, will be a burden to those upon whom it falls; in some cases its effective discharge will cost real money. Safe disposal of some wastes is going to be a tough problem. Some wastes, on the contrary, can readily be handled by inexpensive treatment or by adequate dilution. It is to be expected that the state will take a sympathetic attitude toward those who find themselves faced with disposal problems

and that it will be reasonable in the imposition of restrictions. However, the conservation of water resources for the benefit of this generation and of future generations requires that the situation be faced honestly.

Michigan's rainfall is sufficiently adequate so that the quantitative aspects of water conservation do not yet warrant general concern. In most areas sufficient water is available to maintain ground-water and surface-water levels at elevations determined to be best suited for local land and water use needs. The effects of past errors in surface-water pollution are not necessarily inflicted upon our children, because they can, for the greater part, be corrected at will. This is not true of ground-water contamination. The reservoirs which are contaminated now will stay contaminated for a long, long time and the areas of contamination will gradually expand with the passage of years. The importance of water, especially of ground water, is constantly growing. The public cannot afford to despoil it.

UTILIZATION OF NATURAL PURIFICATION CAPACITY IN SEWAGE AND INDUSTRIAL WASTE DISPOSAL *

By C. J. Velz

Chairman, Department of Public Health Statistics, School of Public Health, University of Michigan, Ann Arbor, Mich.

The objective of this paper is to illustrate the utilization of self-purification capacity of streams without abuse or waste, first, in relation to municipal sewage treatment and disposal; and second, in relation to industrial waste treatment and disposal, particularly, introducing a new principle of conservation—that is, coordinating industrial production with natural purification capacity and water quality requirements.

What is natural purification in a stream? It is the ability of the watercourse to stabilize organic matter without serious impairment of its dissolved oxygen resources, essential to avoid nuisance and maintain aquatic life. This ability varies widely from river to river, from reach to reach of a given river, and changes from day to day with hydrologic fluctuations. Treatment of sewage and waste is not disposal; final disposal is accomplished only in the receiving water through natural purification. Economical and sound stream pollution control, in the last analysis, is judged by how effectively and efficiently the natural purification capacity of streams is utilized.

Natural purification capacity to be utilized must be defined in quantitative terms as to how much, under what conditions, and when it can be depended upon. This can be determined only by stream analysis—a complete appraisal of the oxygen resources of a stream from location to location along its reaches under a wide variety of runoffs, temperatures, and pollution loads. With variation in natural purification capacity defined, it is possible to correlate design and operating patterns with it to take fullest advantage of the inherent resources available.

Drought Probabilities

There are many factors involved in the variation of natural purification capacity: physical features of the river channel, mean depths, occupied channel volumes, natural or artificial deep pools, shallow rapid reaches, the distribution and kind of sources of pollution; and paramount, the runoff and hydrologic patterns of drought. Drought variation is a chance phenomenon peculiar to each drainage basin, but it can be defined by statistical methods. Design and operation of treatment works which will take fullest advantage of natural purification capacity must fit within the framework of the patterns of variation in runoff peculiar to each particular drainage basin.

An excellent means of determining drought probabilities is afforded by the application of the theory of the distribution of largest values developed by Gumbel (1) (2) for flood flows. Gumbel's skewed distribution can be reduced to a straight line form on special probability paper suggested by Powell (3). This probability paper is likewise applicable to distribution of smallest values (droughts) simply by arranging data in the order of severity.

* Presented at 1950 Annual Meeting, Michigan Sewage and Industrial Wastes Association; Traverse City, Mich.; May 22–24, 1950.

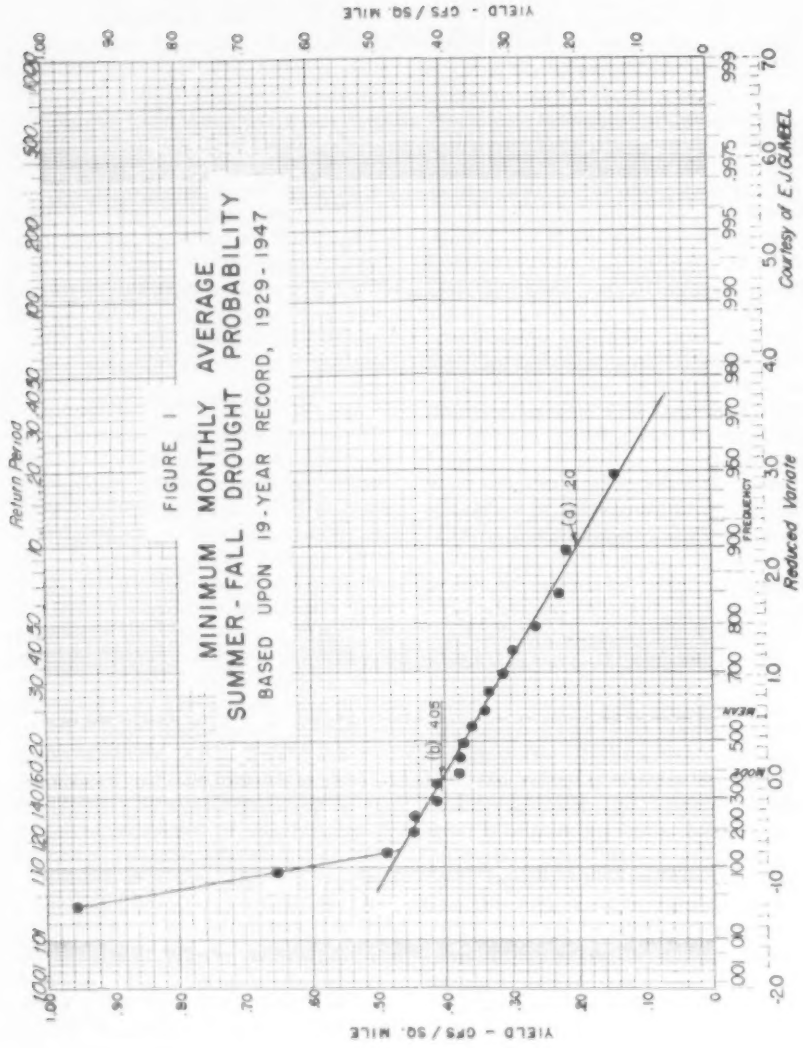


FIGURE 1
MINIMUM MONTHLY AVERAGE
SUMMER-FALL DROUGHT PROBABILITY
BASED UPON 19-YEAR RECORD, 1929-1947
Courtesy of E.J.GUMBEL
Return Period
Reduced Variate
FREQUENCY
MEAN
MODE
(a) 20
(b) 405
YIELD - CFS / SQ. MILE

This places the most severe drought and the most severe flood of a given record in the same relative position in terms of probability.

Figure 1 illustrates a typical minimum monthly drought distribution for a 19-year river record, 1929–47. The lowest monthly average discharge for each year of the summer-fall drought period is selected from the record and rearranged in the order of drought severity, commencing with the least severe. Gumbel has provided a means for obtaining the most probable plotting position, depending on the number of values to be plotted, but a close approximation is afforded by the simple relation $\frac{m}{n+1}$, in which m is the serial number of the value in order of severity and n is the number of values to be plotted. It will be noted from Figure 1 that a reasonably straight line distribution is formed by the more severe drought values to the right of the mode. It is common in dealing with droughts that the less severe values to the left of the mode will break away from the distribution. Such a break may be regarded as defining when a flow is no longer a drought, and is blending back into the normal runoff. Interest lies in the straight line distribution of the real droughts to the right of the mode which relates probability and severity. The ordinate scale (y) of Figure 1 is drought severity in terms of yield, cubic feet per second per square mile (or directly, for a given location, in cubic feet per second). The bottom scale, frequency, is the probability of a drought not exceeding y; the scale at the top, return period, is the average number of years in which a drought as severe as y can be expected once. Thus, for a return period of 10 years, extend vertically to the distribution line (at point a) and then horizontally read on the ordinate scale, 0.20 c.f.s. per sq. mi.

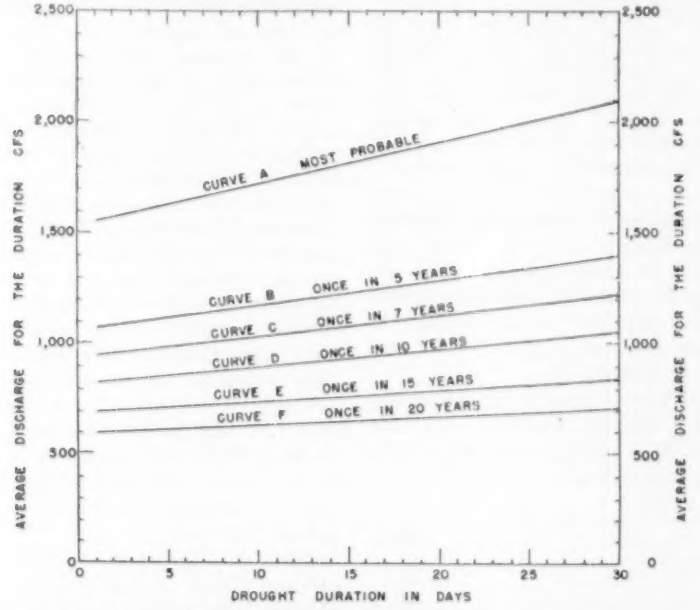


FIGURE 2.—Relationship between severity and duration of drought flow, based on probability studies; record 1928–1948.

This is the drought severity expected in the long run once in 10 years as a minimum monthly average occurring any time during the summer-fall period. The most probable drought flow expected any year is located where the distribution line cuts the mode at point b, in this instance 0.405 c.f.s. per sq. mi. Similarly, for any return period drought severities expected are read directly from the distribution.

This illustration deals with droughts expressed as minimum yields averaged over a period of a month. As the period over which the discharge is averaged is shortened, the drought severity increases; conversely, extremely low flows do not prevail for extended periods. From the standpoint of pollution, consecutive low flow over a period equal to the time of passage through the critical reach of the stream is the significant interval. Usually this is about one week.

Several probability studies of drought flows averaged over different duration periods will define the relation between severity and duration. Figure 2 illustrates the relation developed from detailed studies of one particular river. From this graph, drought flow expected at any time during the summer-fall season as an average over any number of consecutive days from one to thirty days' duration may be obtained. Curve A is the most probable drought expected any year; Curves B, C, D, E, and F designate droughts expected on the average in the long run once in 5, 7, 10, 15, and 20 years, respectively.

From Figure 2 the minimum weekly average drought severities for this river at the particular gage are readily obtained as follows:

Most Probable Drought Expected	Flow (c.f.s.)
Any year	1,650
Once in 5 years	1,125
Once in 7 years	1,000
Once in 10 years	860
Once in 15 years	720
Once in 20 years	610

Drought Severity as a Basis for Sewage Treatment Design

The ability of a particular stream to handle a pollution load by natural purification and maintain a desired dissolved oxygen content in the critical reach at the low point in the D.O. profile is limited by drought severity. Immediately the question arises, what drought severity shall be protected against? And what degree of treatment is required to insure not exceeding natural purification capacity available at such a drought condition? This cannot and should not be decided until a series of D.O. profiles has been computed to define the natural purification capacity available at the various ranges of drought severity, determining the relation between allowable pollution load and runoff to maintain the desired stream condition in the critical reach. This relationship applied to the existing pollution load fixes the reduction in load required for various drought probabilities and establishes the type of treatment necessary. It is then possible intelligently to make a decision as to what is wanted in relation to what can be afforded.

This approach to design for flood control is familiar to all; the same thinking must be applied to stream pollution control. The cost of protection is balanced against runoff probability. Any level of protection can be designed for, but, like any insurance, the cost of the premium is based on the risk. An example illustrates this type of reasoning applied to municipal sewage treatment design for the drought probabilities defined in Figure 2. The stream standards call for D.O. in the critical reach not declining below 40 per cent of saturation, with, however, the question of drought severity to protect against left open.

Based on a series of computed D.O. profiles, Figure 3 represents the relationship between runoff and allowable load to insure, under summer condi-

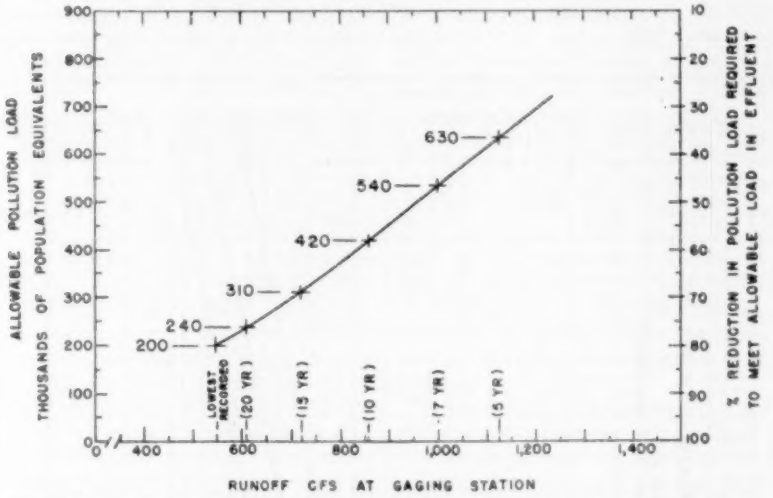


FIGURE 3.—Limiting pollution load to insure dissolved oxygen not declining below 40 per cent of saturation in critical reach at various summer drought flows.

tions of river water temperature of 25° C., dissolved oxygen not declining below 40 per cent of saturation in the critical reach of the river. From this curve, the allowable pollution load to maintain this condition under any drought severity is then readily obtained. For the lowest daily average recorded discharge of 550 c.f.s., the allowable load to be discharged to the river should not exceed 200,000 population equivalents; for drought severities as a minimum weekly average expected once in 20, 15, 10, 7, and 5 years, the allowable pollution loads are 240,000, 310,000, 420,000, 540,000 and 630,000 population equivalents, respectively. These are the limiting loads which may be discharged in the effluent from the municipal treatment works for insurance against falling below the prescribed oxygen level in the critical reach.

In this example, the estimated untreated pollution load for the municipality (sewage and industrial waste connected to the municipal system) is 1,000,000 population equivalents. Knowing the allowable pollution loads permissible under the natural purification capacities at the different drought severities, as defined by Figure 3, the percentage reduction required can be determined, thus defining the degree of treatment necessary. This is shown on the scale on the right of Figure 3 and is summarized in Table I.

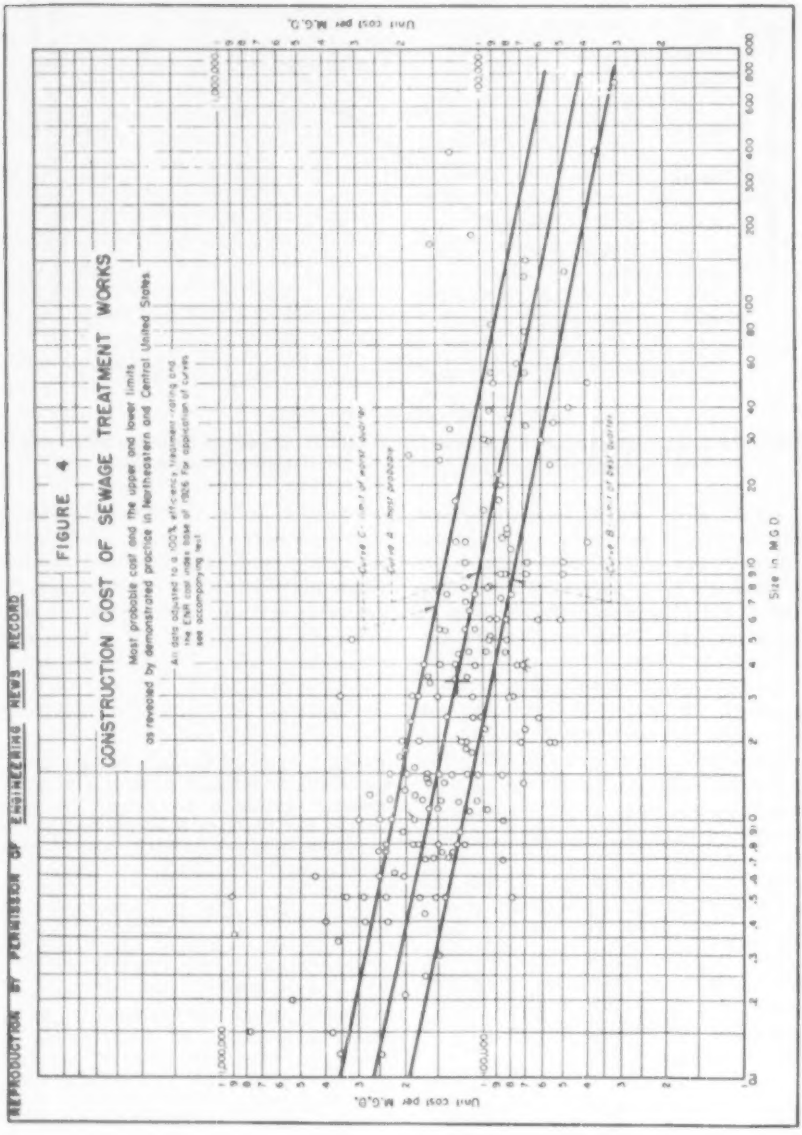
From Table I it is at once apparent

TABLE I.—Relation Between Drought Severity, Allowable Pollution Load, and Required Pollution Reduction to Assure Dissolved Oxygen Not Declining Below 40 Per Cent of Saturation in the Critical Reach of This Stream

Drought Flow[1]		Allowable Pollution Load (pop. equiv.)	Required Reduction[2] (%)
Severity	Min. Weekly Av. (c.f.s.)		
Lowest Recorded	550	200,000	80
Once in 20 Years	610	240,000	76
Once in 15 Years	720	310,000	69
Once in 10 Years	860	420,000	58
Once in 7 Years	1,000	540,000	46
Once in 5 Years	1,125	630,000	37

[1] From Figure 2.

[2] Required reduction for the untreated load of 1,000,000 population equivalents.


REPRODUCTION BY PERMISSION OF ENGINEERING NEWS RECORD
FIGURE 4
CONSTRUCTION COST OF SEWAGE TREATMENT WORKS
Most probable cost and the upper and lower limits
as revealed by demonstrated practice in Northeastern and Central United States
All data adjusted to a 100% efficiency treatment rating and
the ENR cost index base of 1926 for application of curves
see accompanying text
Unit cost per M.G.D.
Size in M.G.D.

that the degree of treatment required is primarily dependent on the drought probability which it is desired to protect against. If it were required to provide treatment which would insure the desired stream conditions during a runoff equal to the lowest recorded flow, notwithstanding taking full advantage of natural purification capacity under that condition, a treatment capable of providing an 80 per cent reduction is called for. This would entail employing some form approaching complete treatment. Similarly, a protection insuring not falling below the desired stream condition more often than once in 20 years would require 76 per cent reduction, again approaching complete treatment. For protection against drought severity expected once in 15 or once in 10 years, reduction required ranges from 69 to 58 per cent, which could be accomplished by an intermediate form of treatment, such as chemical coagulation, high-rate filtration, or modified aeration. In turn, for protection against droughts expected once in 7 to once in 5 years, the reduction required by treatment would range between 46 and 37 per cent, which probably could be obtained by sedimentation. Thus, the choice of drought severity to be protected against would bring under consideration the whole range of treatment from primary to complete, any one of which could be accomplished technically, but the final decision must rest upon a reasonable solution, taking into consideration the economics of the problem.

The estimated average daily volume of municipal sewage in this instance is 100 m.g.d. Employing the cost curves (Figure 4) developed by the writer (4) and the *Engineering News-Record* Construction Cost Index for May, 1950, the cost of construction of treatment works for this capacity can readily be obtained for the various efficiencies of

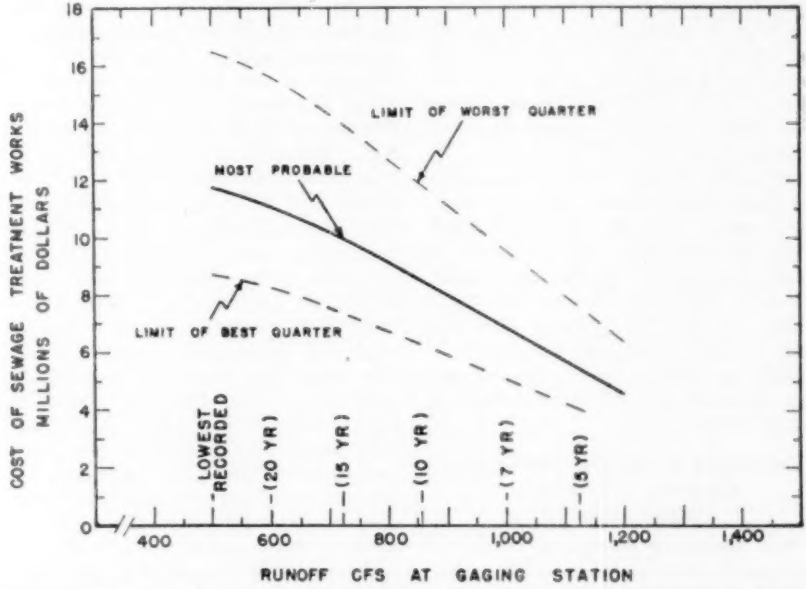


FIGURE 5.—Cost of sewage treatment works for various drought severities to insure dissolved oxygen not declining below 40 per cent of saturation in critical reach.

treatment required. These costs of required treatment works related to runoff and drought severities are summarized graphically in Figure 5. Thus, the most probable cost of construction for treatment works required as protection against a drought severity expected once in 5 years as a minimum weekly average would be $5,500,000; and would increase to $11,900,000 for protection against the lowest recorded droughts. By taking a combination of extravagance, represented by the worst quarter of the practice, and designing for protection against the lowest recorded flow, regardless of the probability of its occurrence, the cost of the treatment works would approach $16,400,000. On the other hand, taking the best quarter of the practice and a reasonable design, protecting against a drought expected on the average once in 10 years, the cost would be approximately $6,200,000.

The elements are now at hand to decide what is wanted in the way of protection in relation to what it will cost. In most instances, municipalities cannot afford to protect against the lowest runoff of record and, generally, economics of the problem dictates protection against drought severity expected once in 5 to once in 10 years.

It is only through this type of analysis that rational and economical sewage treatment design can be obtained with assurance that full utilization is being made of self-purification capacity. Furthermore, design developed upon this type of analysis does not lead to disillusionment, because it is known in advance what risks are being assumed and what protection is being purchased.

Utilization of Natural Purification Capacity in Industrial Waste Disposal

The foregoing discussion refers to design of municipal treatment works. In industrial waste disposal, also, treatment works can be designed to protect against a drought severity expected, say once in 10 years. However, an investment is being made in facilities fully needed, on the average, only once in 10 years; hence, the big majority of the time treatment is being provided far beyond what is needed and, therefore, natural purification capacity is not being fully utilized. If this approach is applied, the limitations of waste treatment are often such that industrial potential in a drainage basin is seriously restricted by the limitations of drought probability. A unique approach, allowing the maximum industrial potential by utilizing natural purification capacity, and at the same time providing positive assurance of meeting stream requirements, is production control correlated to daily stream requirements.

Recently the writer was called upon to evaluate a situation where it was desired to maintain not less than 30 per cent of saturation of dissolved oxygen in the critical reach of the river below an industrial plant. Employing the known methods of waste treatment, to protect against a once-in-10-year drought on this particular stream, it would be necessary to restrict production output to 400 tons of product per day. However, by controlled industrial production coordinated with daily runoff and river water temperature, the industrial potential could be expanded to a daily output of 1,200 tons per day, three times the limit prescribed by continuous operation restricted to meet the 10-year drought condition. Furthermore, there is positive assurance, under the controlled production plan, that the dissolved oxygen will not fall below the desired level under any hydrologic condition and there no longer is assumption of any risks of drought probability. This plan of controlled production entailed, on the average, a net loss in output of only about 1 per cent of full annual production, with curtailment below rated capacity on 10 to 15 days during

the summer-fall season. During some years no curtailment will be necessary; on rare occasions curtailment may reach 3 per cent of full annual production, involving about 40 days.

The success of such a plan of industrial waste disposal depends upon: first, a thorough evaluation of self-purification characteristics under the hydrologic patterns peculiar to the particular stream; second, a careful statistical evaluation of variation in pollution load of the effluent of the waste treatment system per unit of production; and third, the combination of these as a rational guide for production control, so that daily production schedules can be determined from such simple readings as continuous recordings of daily average runoff and river water temperature.

The evaluation of self-purification characteristics involves an elaborate statistical study of hydrologic conditions and an extensive series of computed dissolved oxygen profiles under a wide variety of combinations of pollution loads and the expected hydrologic conditions. Probability of hydrologic conditions is dealt with by methods described hereinbefore. Figure 6 represents one typical D.O. profile computed for a runoff of 500 c.f.s. at the control gage, river water temperature of 35° C., and industrial load of 175,000 population equivalents with upstream municipal load and residual of 111,000 population equivalents—a combination of conditions which produces 30 per cent of saturation in the critical reach below the industry at about Mile Point 170. An extensive series of such computed D.O. profiles forms the major framework for construction of the control curves referred to hereinafter.

The variation in pollution load expected under normal production and operation of the waste treatment works is best obtained from daily records of full-scale operations, or if not available, from pilot plant studies. Figure 7 illustrates the variation in pollution load expected, in this instance based on daily results from one month of normal operation. A reasonably straight line distribution is formed, indicating that operating practice is under con-

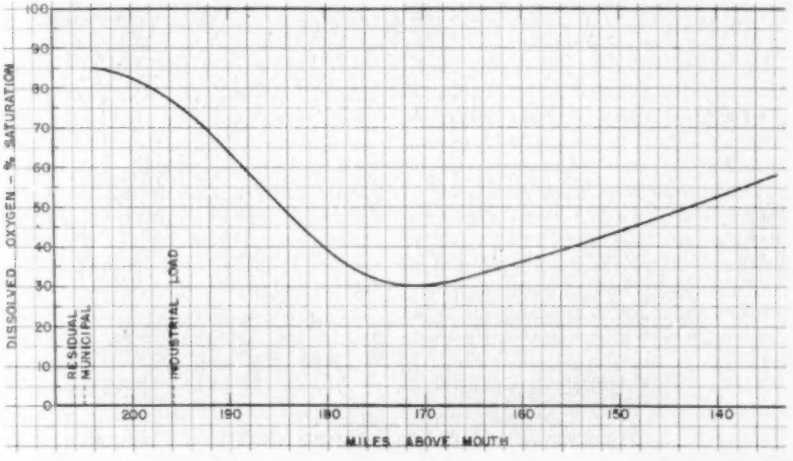


FIGURE 6.—Computed dissolved oxygen profile at 500-c.f.s. flow and water temperature of 35° C., for pollution load comprising: (a) Municipal load—100,000 population equivalents. (b) Upstream residual—11,000 population equivalents. (c) Industrial load —175,000 population equivalents.

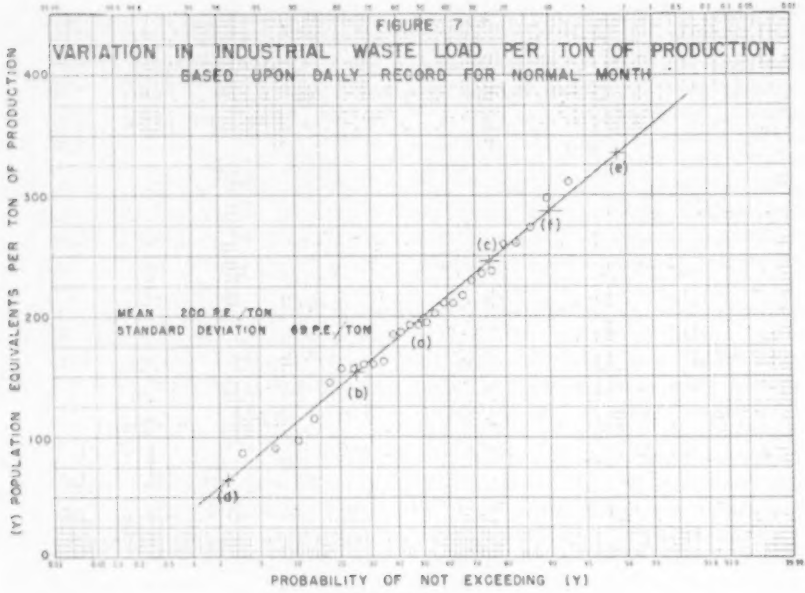


FIGURE 7.

trol. The day to day variation in pollution expected under normal operation is defined by this distribution, with a mean load per ton of production of 200 population equivalents (located at point a) and a standard deviation from the mean of 69 population equivalents. This means 50 per cent confidence that the pollution load will range between 200 ± 46 population equivalents per ton, or 154 to 246 population equivalents, located at points b and c, respectively; 95 per cent confidence that the load will range between 200 ± 135 per ton, or 65 to 335 population equivalents, located at points d and e, respectively. From this it is apparent that normally there is considerable variation in load from day to day.

From the standpoint of stream condition, major interest centers in the chances of having the daily load not exceed a certain value. For example, there can be 50 per cent confidence that the load will not exceed 200 population equivalents per ton (located at point a), or 90 per cent confidence of not exceeding 287 population equivalents per ton (located at point f). If reliance is placed upon the load's not exceeding 200 population equivalents per ton the risk is run of having the load greater than this 50 times in 100, whereas, if reliance is placed on the load's not exceeding 287 population equivalents per ton, only 10 times in 100 would it be expected to be greater than this. In considering the operating practice, which will be discussed hereinafter, the loading at both 50 per cent and 90 per cent confidence limits have been evaluated.

Finally, from such computations a set of basic control curves was developed for this particular river, as shown in Figure 8. From these basic curves it is possible to determine the allowable pollution load which may be discharged by the industry under any runoff or river water temperature, such that dissolved oxygen content in the critical reach below the industry will

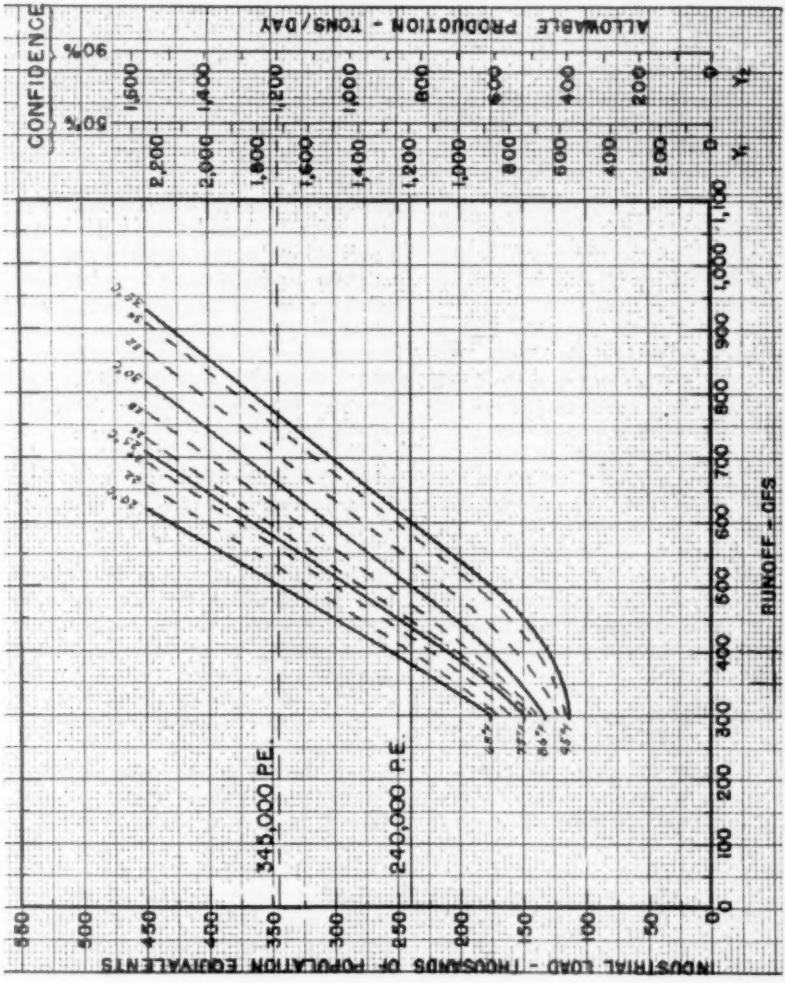


FIGURE 8.—Limiting industrial production to insure dissolved oxygen not declining below 30 per cent of saturation in critical reach at various runoffs and water temperatures.

not decline below 30 per cent of saturation. Scale y_1 relates these conditions to allowable industrial production output in tons per day, with a 50 per cent confidence that the plant waste load under normal operation will not exceed 200 population equivalents per ton. Scale y_2 relates the allowable industrial production output in tons per day with a confidence of 90 per cent that the plant waste load under normal operation will not exceed 287 population equivalents per ton.

Taking the extreme water temperature of 35° C., the limiting runoff permitting 1,200 tons per day production is 600 c.f.s. for 50 per cent confidence that the plant waste load will not be exceeded, and 765 c.f.s. for 90 per cent confidence. Flows this low or lower may be expected to occur during the summer-fall season almost every year. Once in 10 years flow can be expected, as a minimum weekly average, as low as 325 c.f.s. Under these extreme conditions and temperature of 35° C., the production would be limited to about 400 tons. However, by means of these curves it is possible to control production for these limited periods so as to insure against oxygen falling below 30 per cent of saturation.

Basic Curves as a Guide to Mill Operation

An example will illustrate how the basic curves of Figure 8 may be employed as a guide for production practice. Let it be supposed that the runoff as a daily average declines to 500 c.f.s. and the river water temperature is at 30° C. Referring to Figure 8, extend vertically from 500 c.f.s. on the x axis to the curve labeled 30° C.; then extend horizontally to the left ordinate scale and read an allowable pollution load from the industry of 240,000 population equivalents. This is the limiting load under the given runoff and temperature to insure against dissolved oxygen declining below 30 per cent of saturation in the critical reach below the plant outlet. Extending horizontally to the right-hand ordinate scale, y_2, an allowable industrial production is read as 835 tons per day. This is the upper limit of industrial production which would be permitted if it is desired to be 90 per cent confident that the dissolved oxygen profile will not fall below 30 per cent of saturation under the given conditions of runoff and river water temperature.

Taking the same example, but referring to the y_1 scale, the allowable production would be 1,200 tons per day. In this instance, however, there is only 50 per cent confidence that the pollution load discharged under normal operation by the plant would not exceed 240,000 population equivalents. In turn, there is only 50 per cent confidence that with this production the dissolved oxygen would not fall below 30 per cent of saturation in the critical reach. In the first instance, if production is held to 835 tons the risk would be only 1 in 10 of having dissolved oxygen fall below 30 per cent of saturation, whereas in the second instance, with 1,200 tons of production, the risk is 1 in 2. The choice of confidence level depends on the risk one is willing to assume, the consequences of having D.O. fall below 30 per cent of saturation, and the loss entailed by the curtailment of production required.

With the aid of the basic curves it is possible to correlate production and pollution control, providing the daily trends of runoff and river water temperature are carefully followed. From continuous trend graphs of the observed mean daily runoff and water temperature, plus weather forecasts, it would be relatively simple to anticipate the runoff and temperature by several days and plan production levels accordingly.

Summary

Utilization of natural purification capacity of streams is fundamental to

a sound and economical solution of the municipal and industrial waste disposal problem. Unfortunately, with municipal sewage there is no practical way of controlling the source of pollution by varying the quantity produced. Therefore, municipal treatment works must be designed to protect against a drought severity expected on the average once in 5 to once in 10 years, or on some other risk which the situation economically may warrant. As a consequence, this inefficiency in the utilization of investment in providing capacity not fully needed each year must be accepted. However, there is further opportunity for economy in operating costs through correlation with variation in natural purification capacity. With the trend toward flexible treatment systems, certainly seasonal schedules of operation, and possibly weekly schedules, correlated with runoff and temperature, will result in substantial savings in power, chemical, maintenance, and other operating costs.

In industrial waste disposal, however, it is possible to control production, taking full advantage of the daily trend in natural purification capacity. This approach should appeal to regulatory agencies, as well as to industrial management, for it insures meeting required stream quality under any hydrologic condition and at the same time permits increase of the industrial potential in many drainage basins now sorely restricted by the limitations of water resources.

References

1. Gumbel, E. J., "The Return Period of Flood Flows." *Annals of Math. Stat.*, **12**, 163 (1941).
2. Gumbel, E. J., "Flood Flows by the Probability Method." *Eng. News-Rec.*, **134**, 97 (1945).
3. Powell, R. W., "A Simple Method of Estimating Flood Frequencies." *Civil Eng.*, **13**, 105 (1943).
4. Velz, C. J., "How Much Should Sewage Treatment Cost?" *Eng. News-Rec.*, **141**, 84 (1948).

GRAPHICAL REPRESENTATION OF LOAD ON POLLUTED STREAMS

By Karl Imhoff

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American specialists have introduced commendable methods of calculation for predicting the expected oxygen content of a polluted stream. By using these methods, one is in a position to determine the necessary degree of treatment for every source of pollution when low-water oxygen concentrations essential for fish life may not fall below 5 p.p.m. One is also enabled to predict the D.O. curve for whole stretches of rivers (1).

In the following, a simple graphical scheme is described for accomplishing the same result. In effect it is a graphical representation of the "sewage load" of a river. In this usage the term "sewage load" indicates the combined human population and industrial population equivalent per cubic foot per second of the river flow at low stage. Deductions are made for the polluting population in upstream areas according to the self-purification that has taken place during the flow interval.

An example is given in Figure 1. A river 30 miles long must carry the sewage of four towns and two industrial plants (Figure 1d). The towns have a total population of 108,000; the industries' wastes have a population equivalent of 3,900. At low stage, the river flow varies from 0 c.f.s. in the upper reaches to 17.7 c.f.s. in the lower reach, as indicated in Figure 1b.

The curve of self-purification is indicated in Figure 2. In this case, the velocity of flow is taken as being 1.5 ft. per sec., or 26.4 mi. per day. In addition, an estimate as to the percentage of self-purification had to be made according to the peculiarities of the river. At a temperature of 20° C., big rivers show a decrease of about 20 per cent in oxygen requirement within 24 hr. (2). For small brooks of shallow depth the decrease is much greater—about 37 to 50 per cent in 24 hr. (3). In the present example, a daily decrease of 30 per cent is estimated.

The few calculations necessary are shown in Table I. The 30-mi. river length has been divided into three sections, as indicated by the location of the towns, industries, and tributary streams. The results of these calculations are graphically presented in Figures 1a and 1c.

Figure 1c indicates to what extent the sewage must be treated at each outlet along the river. Imhoff and Fair (4) present a sample calculation in which sewage is discharged to a river after only primary settling, due to the D.O. curve not dropping below 5 p.p.m. (at a temperature of 25° C.) provided that the sewage load is not more than 3.2 c.f.s. per 1,000 population, or 310 population per c.f.s. In Figure 1c, however, the sewage load is between 1,200 and 5,800 population, or far above the limit of 310 population. In the present example, therefore, complete treatment is necessary for all discharges; settling tanks will not suffice.

In Germany, this limiting factor is higher (specifically, at about 850 population per c.f.s.). The German rivers, therefore, may be more heavily loaded, as regards contributory population, than American rivers. The higher lim-

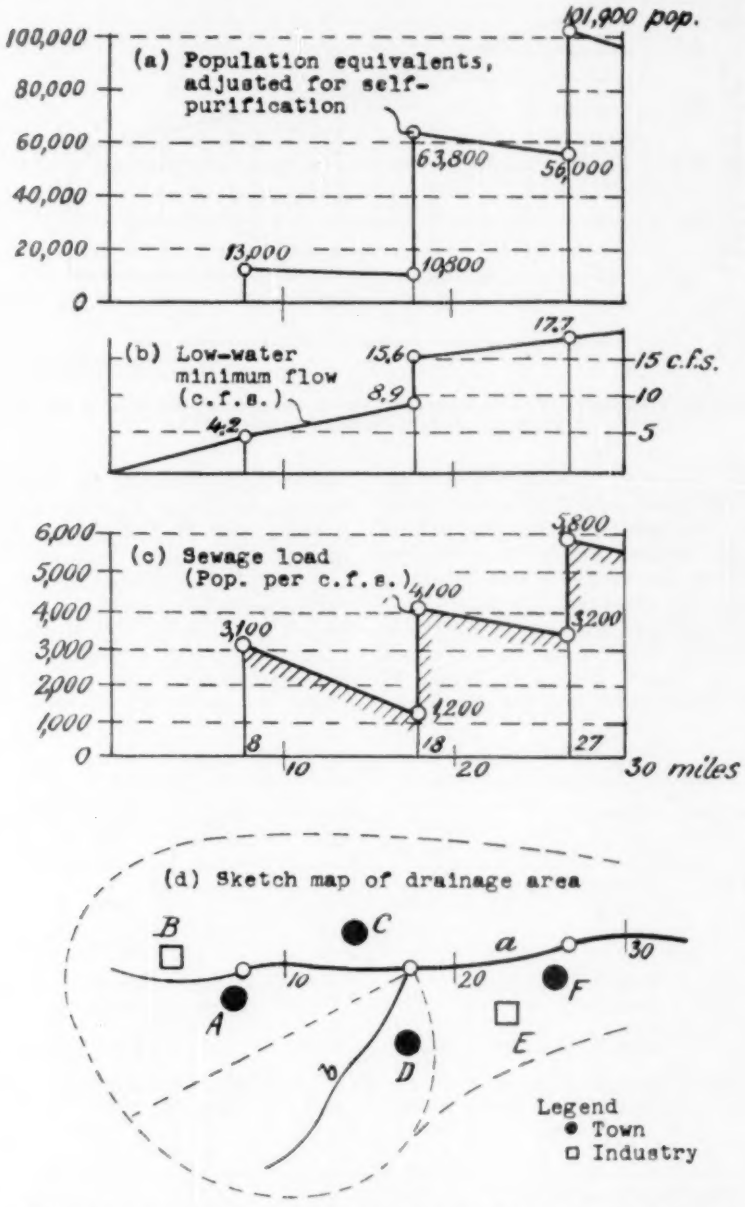

FIGURE 1.—Example of graphical representation of load on a polluted stream.

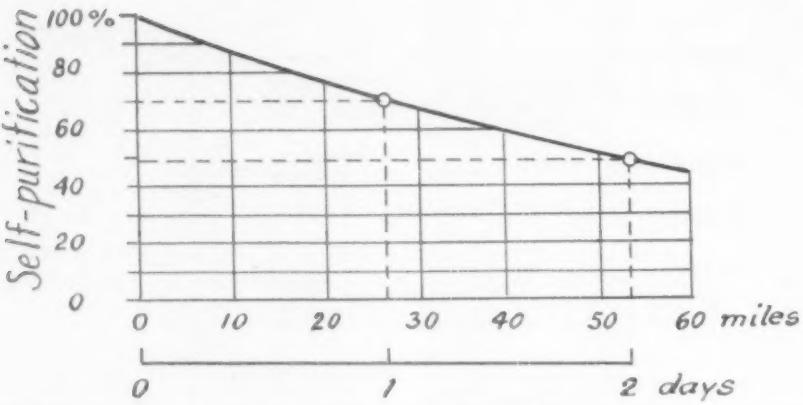

FIGURE 2.—Stream self-purification curve for an assumed velocity of 1.5 ft. per sec. and 30 per cent oxygen demand decrease in 24 hr.

iting factor for German rivers is due to the lower individual sewage pollution contribution in Germany and the lower water temperatures involved (20° C., as compared with 25° C. in American rivers).

Sewage load schemes of this type as set up in 1947 for the German rivers, Rhine, Weser, Elbe, and Danube by the Cooperative Institute for Water Science (Bundesanstalt für Gewässerkunde), located at Bielefeld, in conjunction with H. Dahlem, consulting engineer, Essen, have been published (5). The curves of sewage load gave values below 850 population per c.f.s. for all four streams; only at one place —on the Elbe near Dresden—was this limit exceeded. In the one instance where the limit is exceeded (and

TABLE I.—Sample Calculation of the Sewage Load on a Stream

Low-Water Flow (c.f.s.)	Stream, Town, or Factory[1]	Contrib. Pop. Equiv.		Length of Section (mi.)	Previous Load, Correction[2]	Total Pop. Load[3]	Sewage Load[4] (pop. per c.f.s.)
		Each Unit	Total Local				
4.2	Town A	10,000				a) —	
	Fact. B	3,000	13,000	8.0	—	b) 13,000	
						c) 13,000	3,100
8.9	Town C	35,000			83% of	a) 10,800	1,200
15.6	Stream b	—			13,000	b) 53,000	
	Town D	18,000	53,000	18.0		c) 63,800	4,100
17.7	Town F	45,000			88% of	a) 56,000	3,200
	Fact. E	900	45,900	27.0	63,800	b) 45,900	
						c)101,900	5,800

[1] See Figure 1d for location.
[2] Self-purification correction from Figure 2.
[3] Total population load, made up of (a) corrected previous load and (b) local load.
[4] Column 7 divided by Column 1.

where there presently are not even primary settling tanks), complete treatment of the sewage would be necessary. Otherwise, primary treatment of sewage is still sufficient for the large German rivers.

References

1. Imhoff, K., and Fair, G. M., "Sewage Treatment." Pp. 305–327. John Wiley & Sons, New York (1940).
2. *Ibid.*, p. 38.
3. *Ibid.*, p. 297.
4. *Ibid.*, p. 325.
5. Imhoff, K., "The Sewage Load of German Rivers." *Gesundheitsingenieur*, **68**, 108 (1947).

STATISTICAL SUMMARY OF SEWAGE WORKS AVAILABLE

The Public Health Service, Federal Security Agency, announces that copies of its report entitled "Statistical Summary of Sewage Works in the United States," Supplement 213 to "Public Health Reports" (see THIS JOURNAL, **22**, 7, 887; July, 1950), may be obtained from the Water Pollution Control Division, Public Health Service, Washington 25, D. C. The report summarizes basic data on the country's sewage works which first appeared in the "1945 Inventory of Water and Sewage Facilities," a Public Health Service survey covering all communities of over 100 population in the United States.

BACTERIAL SURVEY OF STREAMS AND BATHING BEACHES AT CLEVELAND*

By John S. Delos

Senior Chemist, Easterly Sewage Treatment Plant, Cleveland, Ohio

The subject of water quality as related to Cleveland, Ohio, is now almost 100 years old. The Cleveland water works was begun in 1854. In 1912, Jackson (1) prepared an extensive report on the sanitary condition of the Cleveland water supply. There have also been the routine tests performed by the Water Department and the City Health Department. The Easterly sewage treatment plant studies were started in 1938, the first of which was reported by Van Gieson (2). In 1947, a review was made of the existing data on the sanitary quality of the Lake Erie beaches at Cleveland (3).

During 1949, a great deal of interest in the shore-water quality was created by articles appearing in public print. "Pollution" stories have now reached the enviable position of feature front-page material for newspapers. It has become a popular subject! In Cleveland it is believed that advantage should be taken of the situation for the improvement of the lake front.

This paper is a condensation of the original report submitted to the Commissioner of Sewage Disposal and comparison is made only with the studies of the Easterly sewage plant for the years 1938 through 1941 and in 1946. The 1949 survey started July 5 and ended September 27. It included the sampling stations of previous years, plus two new lake stations and four streams. The 1949 survey was more extensive than in any previous year and differed, also, in that approximately 25 per cent of the samples were taken during September, whereas previous studies included very few, if any, September samples.

The objects of the 1949 survey were:

* Presented at 1950 Annual Meeting, Ohio Sewage and Industrial Wastes Treatment Conference; Cincinnati, Ohio; June 28–30, 1950.

TABLE I.—Bathing Beach, Other Lake, and Stream Stations Sampled in Bacterial Survey at Cleveland

Station				Sampling Period
Type	Designation	Location	Map Designation[1]	
Bathing	Gordon Park	East Blvd. and Lakefront	D	July, Aug., Sept.
Bathing	White City	E. 140th St.	G	July, Aug., Sept.
Bathing	East 185th St.	E. 185th St.	M	July, Aug., Sept.
Bathing	Beachland	Sunset Road	L	July, Aug., Sept.
Bathing	Euclid Beach	E. 158th St.	K	July, Aug., Sept.
Bathing	Villa Beach	E. 148th St.	H	July, Aug., Sept.
Lake	East 26th St.	E. 26th St.	B	Sept.
Lake	East 55th St.	E. 55th St.	C	Sept.
Stream	Cuyahoga River	R.R. bridge N. of Front Ave.	A	Aug., Sept.
Stream	Doan Creek	At Gordon Park	E	Aug., Sept.
Stream	Nine Mile Creek	Just S. of lake	F	Aug., Sept.
Stream	Euclid Creek	S. of Lake Shore Blvd.	J	Aug., Sept.

[1] See Figure 1.

1. To determine the present level of pollution of the bathing beaches, as compared to the prewar level.
2. To determine the effect of storm-water overflows on the pollution level.
3. To determine the quality of water flowing in the streams discharging into the lake.

One sample was taken each sampling day at each of the stations given in Table I and shown on map (Figure 1). Samples were generally taken between 8:30 and 11:00 A.M.

The lactose broth fermentation tubes are reported as coliform bacteria per milliliter, in the most probable number according to Hoskins (4). Two tubes were used in decimal dilution and all averages are arithmetic. Only doubtful 48-hr. tubes were confirmed in brilliant-green bile broth.

The summer was unusually hot and dry, as shown by a statement from the official Weather Bureau report, as follows:

"Record breaking temperatures during June and July continued through August, producing Cleveland's warmest summer season on record. Drought conditions prevailed from July 23 to August 27."

Only 1.42 in. of rain (recorded by the Euclid-East 24th St. Station) fell during the drought period. September was the first month since October, 1948, with a mean temperature below normal. Frequent rains during the month caused the storm-water overflows to operate often, and high winds caused much turbulence of the shore water.

Preliminary Bacteriological Work at White City Beach

Prior to the general beach survey, White City Beach was surface sampled at six numbered points on four days. The lateral separation of the points was such that the entire beach was covered. The points were about 50 ft. apart. Three samples were taken where the water was 1 ft. deep and three samples where the water was 5 ft. deep. The M.P.N. colon count is tabulated in Table II.

TABLE II.—Average M.P.N. Coli per Ml. at White City Beach (Preliminary to Beach Survey)

Date (1949)	Conditions	M.P.N.			Overflow Hours	
		Av.	Max.	Min.	Main	Coll.
July 5	Clear	72	230	13	—	—
July 6	Clear	62	70	24	2.3	3.3
July 7	Cloudy	78	240	6	—	—
July 9	Overflow	—	—	—	7.8	11.8
July 11	Clear	63	130	13	—	—

July 7 was the only cloudy day and there was no local rain. As the last overflow occurred two days before sampling, it appears to have little influence on the average for July 11 and indicates, along with observations made throughout the season, that with favorable conditions a beach returned to a normal condition 24 to 48 hr. after cessation of rain. The July 6 overflow did not seem to influence the daily average to any extent.

The deviation of values shown (for example, on July 7 the maximum was 40 times the minimum) clearly indicates the necessity of taking multiple samples at a particular point, in order to establish the pollution level with a fair amount of certainty. It also indicates that single daily samples considered individually may be very misleading as to the true condition of a particular beach. However, due to lack of personnel, daily multiple sampling of individual beaches was not carried out in the regular survey.

Beach Survey Results

Table III shows the monthly and seasonal averages for each beach during the 1949 survey. The rise in values from August to September is worth noting. Table IV shows the averages for each beach for the years of the sewage plant analyses.

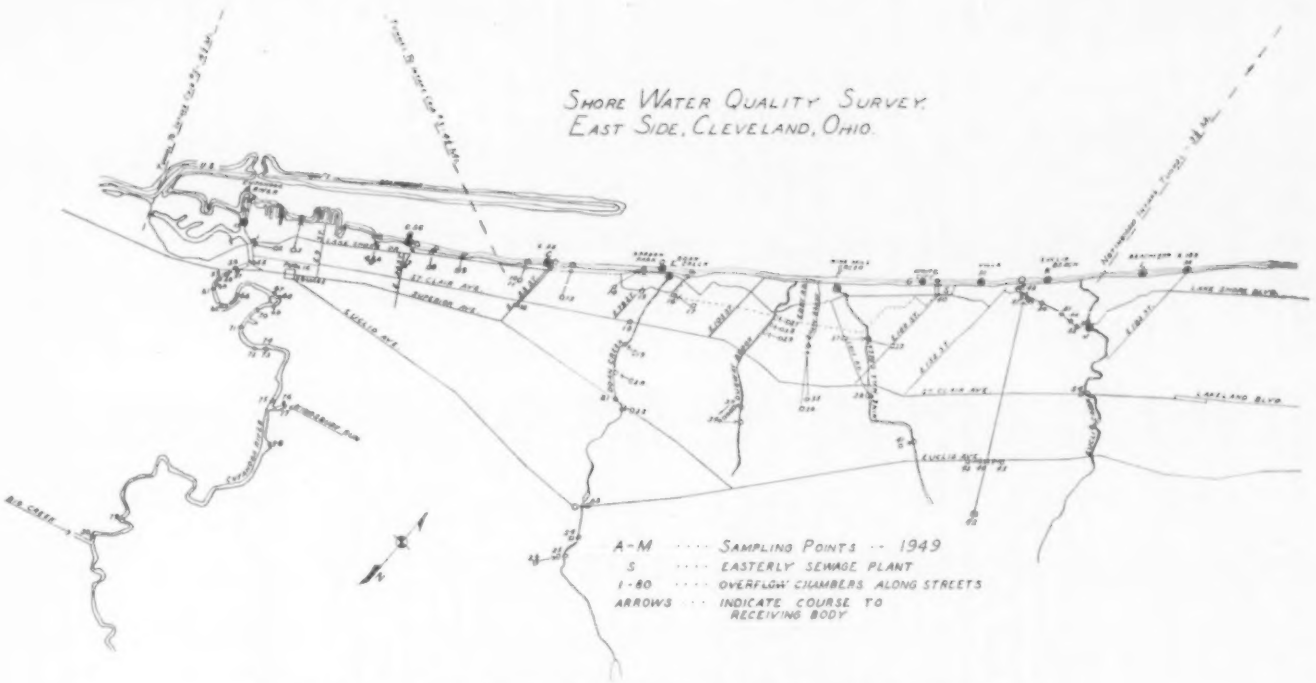
SHORE WATER QUALITY SURVEY.
EAST SIDE, CLEVELAND, OHIO.
A-M .... SAMPLING POINTS -- 1949
S .... EASTERLY SEWAGE PLANT
1-80 .... OVERFLOW CHAMBERS ALONG STREETS
ARROWS ... INDICATE COURSE TO RECEIVING BODY

FIGURE 1.—Location of sampling stations and storm-water overflows in bacterial survey of streams and bathing beaches at Cleveland.

TABLE III.—M.P.N. Coli per Ml., 1949 Beaches

Period	Beach						
	Gordon	White City	E. 185	Beachland	Euclid	Villa	All
July	120	100	190	89	180	70	130
August	260	91	140	46	250	170	160
September	320	390	210	190	200	220	260
Seasonal	200	190	180	110	210	150	180
No. Samples	43	68	43	43	43	43	283

Discussion of the Over-all Pollution

The 1949 values are higher than for other years. In evaluating and comparing the results of the 1949 survey with previous and more limited surveys, the following should be kept in mind. The September results, affected as they were by rainfall and stormy weather, were by far the worst of the season and affected seasonal averages of each beach to a considerable extent. The previous surveys included very few, if any, September samples. Although the results of the 1949 survey cannot be strictly comparable to the previous surveys, it is felt that the 1949 survey, by including these figures, does show how the pollution level can be increased considerably by adverse weather conditions.

An analysis of the individual beaches for the prewar period of 1939–1941, as compared to 1949, shows almost without exception that each of the beaches has deteriorated to a higher pollution level. Even when the September, 1949, results are omitted from the 1949 data, the pollution level is appreciably higher than it was in the prewar period.

The combined averages for the prewar and the 1949 periods are shown in Table V. The 1938 figures are omitted because the data was collected before the Easterly sewage treatment plant was placed in operation.

In 1912, according to Jackson (1), the Board of Health closed the beaches as unsafe for swimming when coliforms were found in 10, 1, and 0.1 cc. In 1949, coliforms were found in 0.1, 0.01, and 0.001 cc. and swimming was apparently condoned! In fact, gassing occurred in 0.001 cc. for 18 per cent and in the 0.01 cc. for 62 per cent of the 283 samples.

TABLE IV.—M.P.N. Coli per Ml. for Each Beach

Beach	Survey Year					
	1938[1]	1939	1940	1941	1946	1949
Gordon	80	94	115	63	180	200
White City	1,400	150	86	79	45	190
East 185	890	80	59	58	30	180
Beachland	200	66	100	49	110	110
Euclid Beach	690	68	74	160	160	210
Villa	650	230	88	82	100	150
All beaches	650	110	87	82	100	180
No. samples	49	106	113	99	46	283

[1] Values recorded before Easterly sewage treatment plant opened.

Other Lake Stations

As the survey progressed, it was decided to secure some information regarding the condition of the lake between the Cuyahoga River and Gordon Park, the first beach. Unfortunately, as the period sampled was one with the highest values for the beaches, it may

TABLE V.—Combined Averages of Prewar and 1949 Periods

Item	Period		
	3-Yr. Period 1939–1941	1949 July-Aug.	1949 July-Aug.-Sept.
M.P.N. (coli/ml.)	93	142	180
No. samples	318	217	283

TABLE VI.—Comparison of the Lake Points Other Than Beaches

	Sampling Point	
	E. 26 St.	E. 55 St.
M.P.N. (coli/ml.)	100	920
Maximum	240	7,000
Minimum	<10	13
No. samples	8	8

be concluded that these two points also showed higher values than they would have during July and August. The results are summarized in Table VI. The wide difference in the averages of the coliform figures suggests the presence of a strong source of pollution at East 55th Street.

Effect of Storm-Water Overflows on Beach-Water Quality

The City of Cleveland maintains a combined storm and sanitary sewer system, with overflow chambers located at various points along the main intercepting sewer and at other points throughout the city. Data are not available showing the times that these overflows operate. At the Easterly sewage treatment plant are located the Main and Collinwood overflows; records are maintained showing the number of hours these overflows operate. This information may be used as a rough index regarding the times of operation of the other overflows. Because these overflows empty into the lake, they contribute to the pollution and have an influence on the data obtained.

The accompanying map (Figure 1) shows the approximate location of some of the overflow chambers having an influence on the colon count of the sampling points. The overflows are usually located along streets, whereas the point of discharge is indicated by an arrow near the receiving body.

Data taken from the records of the Department of Sewers, showing the sill height (point which water must reach before it overflows) and the height of the flow on inspection dates for some of the chambers, are tabulated in Table VII. Many of the chambers were operating at 50 to 75 per cent of capacity, so that overflows due to storms were quite probable.

Inspection of Figure 2 shows that rain on consecutive days tends to raise the coliform count of the beaches and the beaches require a longer period for recovery as compared with rain for a single day. For a given period, the number of days of rain has a greater effect than the amount of rain which fell at a particular period. Analysis of the data (Figure 2) indicates that the most favorable period during the summer, as far as rain and storm overflows having the least effect on beach water, was from July 31 through August 25. The rainfall and time of storm-water overflows during this period was about the optimum as far as weather conditions ever permit, and it can be assumed that the existing level of pollution would be due mainly to causes other than the operation of storm-water overflows. On the other hand, rainfall and storm-water overflow operations during the periods July 24 to July 28, and August 28 to September 8, served to produce two periods of the most unfavorable beach-water conditions.

During the favorable dry-weather period, it can be seen from Figure 2 that the highest daily per cent of samples with a M.P.N. of 25 or more oc-

TABLE VII.—Overflow Chamber Data

Location	Sill Height (in.)	Flow Level (in.)[1]
E. 140 St. at Lake Shore Blvd.	72	59 to 69
Eddy Road at Ablewhite	7	5 to 7
University Circle	24	21
Dugway at East 106 St.	6	4 to 7
Coit at Kirby	9	6 to 8
Coit at E. 145 St.	10	5 to 7
E. 20 St. at Lakeside	20	16 to 18
E. 40 St. at Lakeside	20	16 to 17

[1] On date inspected.

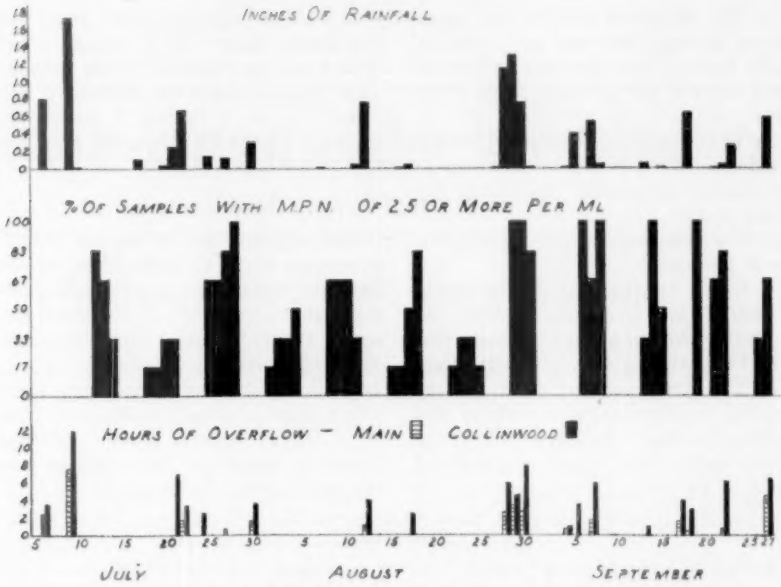

FIGURE 2.—Comparative 1949 data on rainfall, coliform M.P.N., and storm-water overflow periods.

curred on August 18 following rain and overflow conditions, which existed on August 17, but did not take place until after collection of the August 17 samples. Another overflow and rain occurred on August 12, but apparently did not affect the August 15 samples.

The data in Table VIII serve to present the information relative to beach water conditions during favorable and unfavorable periods, as judged by rainfall and storm-water overflow operation. The coliform count definitely increased during the wet period.

TABLE VIII.—Comparison of Dry and Rainy Periods

Period	Rainfall (in.)	Overflow Period (hr.)		M.P.N. (coli/ml.)	No. of Samples
		Main	Coll.		
July 31 to Aug. 25	0.87	1	6.3	120	96
July 24 to 28 and Aug. 28 to Sept. 8	5.49	12.5	42.7	360	60

TABLE IX.—Stream Data Averages

	Stream			
	Cuyahoga River	Doan Creek	Nine Mile Creek	Euclid Creek
Av. M.P.N. (coli/ml.)	1,000	4,700	9,900	4,000
Maximum	2,400	24,000	70,000	24,000
Minimum	230	60	<10	<10
No. of samples	18	18	18	18

Stream Samples

Stream sampling was decided upon later in the season, in order to gain some information regarding the quality of the water in the streams. Table IX shows that these streams are contributing to the pollution of the lake.

Summary

Although the 1949 survey was somewhat limited in scope, it has indicated that the following conclusions are justified:

1. The pollution level of the beach waters during 1949 was at a substantially higher level than that which existed during the prewar years 1939–1941.

2. The Cleveland beaches are polluted several times over any known permissible standards established for beach water.

3. The pollution level of the lake water is increasing.

4. Rainy weather and the operation of storm-water overflows increase the pollution level to a much higher value than that existing during dry weather.

5. The proximity of some of the beaches to storm-water overflows and polluted streams indicates why some of the beaches are dangerously polluted much of the time.

6. Stream samples taken from the Cuyahoga River, Doan Creek, Nine Mile Creek and Euclid Creek indicate that these streams are extremely polluted and are a source of continuous discharge of polluted water into the lake.

Acknowledgments

The author wishes to express his appreciation to E. C. Richardson, of the Engineering Department; the Department of Sewers; the U. S. Weather Bureau; W. E. Gerdel, superintendent, Southerly sewage treatment plant; John J. Wirts, superintendent, Easterly sewage treatment plant; and Walter F. Shaw, operator, Easterly sewage treatment plant, for their assistance in the preparation of this paper.

References

1. Jackson, D., "Report on the Sanitary Condition of the Cleveland Water Supply." (1912).

2. Van Gieson, P., "Studies of Bathing Beach Waters of Cleveland." Fifteenth Ann. Rep., Ohio Conf. on Sewage Treat., p. 39 (1941).

3. LeBosquet, M., Jr., "A Review of the Existing Data on the Sanitary Quality of Lake Erie Beaches at Cleveland, Ohio." (1947) Unpublished.

4. Hoskins, J. K., "Most Probable Numbers for Evaluation of Coli-Aerogenes Tests by Fermentation Tube Method." *Pub. Health Rep.*, **49**, 393 (1934).

THE OPERATOR'S CORNER

CONDUCTED BY HERBERT P. ORLAND

CATCH UP, KEEP UP, AND PLAN AHEAD

Is your plant one of those that still has war-born "deferred" maintenance, perennially delayed or put off because of a hope that high wage and material costs will some day miraculously return to what is nostalgically called "normal"? Or is it one of those whose physical condition and financial situation is such that there is a multiplicity of minor maintenance items simply being put off from day to day because of lack of money, man power, or planning?

Both these categories of "deferred" maintenance no longer have a place in plant management. World affairs are in such a state that peace may be rudely shattered again at any time. Preparation for added defense requirements puts on each individual manager the responsibility of seeing that there is no "deferred" maintenance at his plant. In an essential service such as sewage or industrial wastes treatment, to enter the period of uncertainty now facing us with essential maintenance, repairs, or replacements unfinished, let alone unstarted, is to blindly ignore the aggravations and frustrations of the past ten years. No one wants to be caught again with "too little too late!"

As a part of the general preparedness program advance plans also should be made for more flexible operation to meet emergencies, particularly those resulting from war-born circumstances. Plans for handling overloads, equipment or power outages, personnel shortages, etc., should be drawn up ready for immediate implementation when needed. Maintenance and operational inventories, as previously pointed out in these pages (THIS JOURNAL **22**, 11, 1482; Nov., 1950), should be built up to safe points on a sound, sensible basis.

All this planning has probably been done to some degree or other at almost every plant. Nevertheless, there doubtless are very few plants where anyone but the head man knows what is planned in the several directions mentioned, and even fewer where the plans are intelligibly down in black and white for the guidance of a possible "pinch hitter." If something should happen to you today, would the man taking your place have any idea at all as to what you were trying to do?

Yesterday is gone—but yesterday's effects are still with us, even if only in memory. This alone should be a strong incentive to get caught up and to keep caught up with maintenance affairs, and to plan soundly for the future. It is just as much a part of that planning, however, to keep it alive and provide the flexibility needed to "roll with the punches," as it is to provide operational flexibility against plant shock loads. Let no day pass without doing something to reduce the deferred maintenance requirements at your plant!

H. P. O.

WINNIPEG'S SEWER SYSTEM IN THE 1950 FLOOD*

By W. L. Wardrop

Engineer of Water Works and Sewerage, Winnipeg, Manitoba

The year 1950 will long be remembered as the year the people of the Red River Valley found themselves held at the mercy of the Red River. Not since 1861 had the Red River reached the flood stage that was recorded in 1950.

Although the flooded area within the City of Winnipeg only amounted to approximately seven per cent, the effects of the flood extended over the entire city through the flooding of one of the essential services—the sewer system. Before discussing some of the problems imposed through a flooded sewer system, it would be desirable to consider some of the factors pertaining to the flood situation in the Red River Valley. It is believed that, in this way, a more complete appreciation can be gained of the importance of the sewer system in relation to floods.

Winnipeg is situated at the confluence of the Red and Assiniboine Rivers, 40 mi. south of Lake Winnipeg, 60 mi. north of the boundary line between Canada and the United States, and at an elevation of 760 ft. above mean sea level. It extends over an area of 25 sq. mi. and is particularly vulnerable to flooding because of its relatively flat terrain. The difference between the highest and lowest street elevation, exclusive of bridges and underpasses, is less than 20 ft. Winnipeg and suburbs have a population of approximately 368,000 and constitute by far the largest concentration along the Red River.

The Red River, formed at Breckenridge, Minn., by the junction of the Bois de Sioux and the Otter Tail Rivers, follows a winding course through the center of a flat valley once covered by Lake Agassiz, and empties into Lake Winnipeg. Its course, measuring approximately 550 mi. with an average slope of 0.5 ft. per mile, is nearly twice as long as the direct distance. Owing to the relatively slight fall in the stream bed, the flow velocities are too low to erode a channel of sufficient capacity to carry the volumes of water present under flood stages. Red River is the outlet channel for the many tributary streams that provide drainage for the combined areas of the Red and Assiniboine Valleys, estimated to cover approximately 100,000 sq. mi., 40 per cent of which lies in the Red River Valley south of Winnipeg.

Historical records reveal that the present site of Winnipeg has been subjected to at least 12 major floods during the past two centuries, that is, floods in which the river elevation was at least 5 ft. above minimum flood stage, or 23 ft. above city datum. (City datum equals 727.57 ft. geodetic.) The flood of 1826 was the worst on record. During that year, the water is believed to have risen to 36.75 ft. above city datum, or approximately 6 ft. above the 1950 peak of 30.3 ft.

The fact that the Red River flows northward through an area heavily icebound in winter greatly influences its flood characteristics. Spring break-up in the headwaters of the Red River is normally from two to three weeks earlier than in Winnipeg. Therefore, ice retardation is a factor in the early stages of spring flooding.

The heavy rains which occurred generally throughout the Valley during the early part of May certainly aggravated the flood situation. Rainfalls of 0.62 in. and 1.32 in. were recorded at Winnipeg on May 4 and 5, respec-

* Presented at 17th Annual Convention, Canadian Institute on Sewage and Sanitation; Bigwin Inn, Lake Of Bays, Ontario; Sept. 11-13, 1950.

tively. During the evening of May 5, the Red River, already at the 24.9-ft. stage, rose at the rate of 1 in. per hr. By May 10, the river had reached an elevation of 29.0 ft., a rise of over 4 ft. in five days. The Red River crested at Winnipeg on May 19 at an elevation of 30.3 ft. with a discharge of approximately 101,000 cu. ft. per sec.

It is interesting to note from a comparison of the hydrographs of the 1950 spring flood, as recorded at various points in the valley, that the Red River crested twice—the first crest reached Winnipeg on May 5, simultaneously with the peak of the storm; the second crest came on May 19, but a cessation of the rain made the second crest period less disastrous.

Prevention of a catastrophe such as is foreseeable by the combination of possible events of river and weather conditions can only be forthcoming after extensive investigations by hydrologists. In the meantime, it is satisfying to know that steps are being taken to construct a system of dikes throughout the lower areas of Greater Winnipeg, which will provide protection against future floods below the nominal peak of 26.5 ft. above city datum. This work is being carried out under the direction of the Greater Winnipeg Diking Board, which was set up on June 28, 1950, by authority of the Provincial government. Preliminary plans have already been completed and it is expected that actual construction will be commenced in the near future.

The initial project consists of approximately 15 mi. of dikes in the form of a "broad boulevard" constructed on a standard 66-ft. street right-of-way. The top of the dike, which is to be 50 ft. wide, will provide a 38-ft. roadway with a 6-ft. sidewalk strip on either side. This will allow two lines of truck traffic to circulate on the side of the boulevard away from the river, leaving space on the river side to build up, during an emergency, an earth dike to an additional height of 6 ft. and still maintain a 10-ft. top with 1½ to 1 slopes. A point which should be noted is that the proposed dikes, in a good many cases, will be constructed along streets which contain existing underground utilities. Sewer manholes and catch basins will have to be extended. The cost of maintenance of the water and sewer systems will be increased considerably by reason of the extra depth superimposed by the construction of the dikes.

Another important part of the protective plan proposed by the Board is the construction of at least 21 pumping stations throughout the metropolitan area to clear the sewers of storm waters during periods of high water. It is extremely gratifying to know that these protective measures are forthcoming and will help to bridge the gap between now and the time when a larger scheme of flood protection can be brought into being, which period was estimated by the Commission to be at least five years.

Description of Sewer System

The City of Winnipeg is divided into 20 sewer districts. Until 1937, trunk sewers from each district emptied into the Assiniboine or Red Rivers. With the completion of the Greater Winnipeg Sanitary District treatment plant and interceptor sewer in 1937, approximately three times the dry weather flow in each of the trunk sewers connected to the interceptor was diverted through the treatment plant. The balance of the flow goes to the river through outlet sewers. Winnipeg sewers are of the combined type and total approximately 325 miles, ranging in size from 1 to 10 ft. Owing to the relative flatness of the area and the construction difficulties, it was impractical to have the interceptor low enough so that all trunk sewers could deliver to the interceptor by gravity. Consequently, 16 automatic pumping stations were installed in the system, with 9 of these located within the present

city limits. Before any sewage enters the interceptor, it passes through comminutors. All but two of the 21 trunk sewers connect to the interceptor. There are 22 sewer outlets to the rivers, with all but four protected by flood gates. The river outlet sewers range in size from 5 to 8.5 ft. The main interceptor is circular in shape and varies from 3.5 ft. in diameter at the upper end to 7.5 ft. in diameter at the lower end; it is 7.5 mi. long. The present capacity of the pumping facilities at the treatment plant is 82.5 m.g.d.

Control under Flood Conditions

Few people fully appreciate the difficulties in maintaining control of a large sewer system under flood conditions. This control depends on (1) the ability to keep flood waters out of the system and (2) having sufficient pumping capacity to clear the sewers of storm waters. It would be a serious mistake to underestimate the task of keeping flood waters out of the system, as the success or failure of any protective scheme depends on the extent to which this can be accomplished. By May 6, control was lost within the city in all but two of the districts.

One of the difficulties in maintaining control is the fact that a number of the districts are physically interconnected at the ends remote from the rivers. Under normal conditions, the districts operate independently; under flood conditions, they may operate as a single district. A more serious problem, of course, is the unknown underground connection, which is extremely difficult to trace. There is also the problem of something becoming lodged in the flap-type flood gate, which may prevent it from completely closing. For this reason, it is believed that consideration should be given to a more positive type gate, such as stop logs or sluice gates.

Unless control of the sewers can be maintained, it is difficult to prevent the flooding of the remote low-lying areas. In some cases, curb outlets were blocked and manholes and catch basins extended to prevent this type of flooding (see Figure 1).

However, this necessitated considerable local pumping during rain storms, as there was no place for the water to escape. It is an unforgettable experience to witness water gushing up from manholes and catch basins. During the early morning of May 6,

FIGURE 1.—Excessive flooding by overflows prevented by extending sewer manholes and catch basins with sandbags.

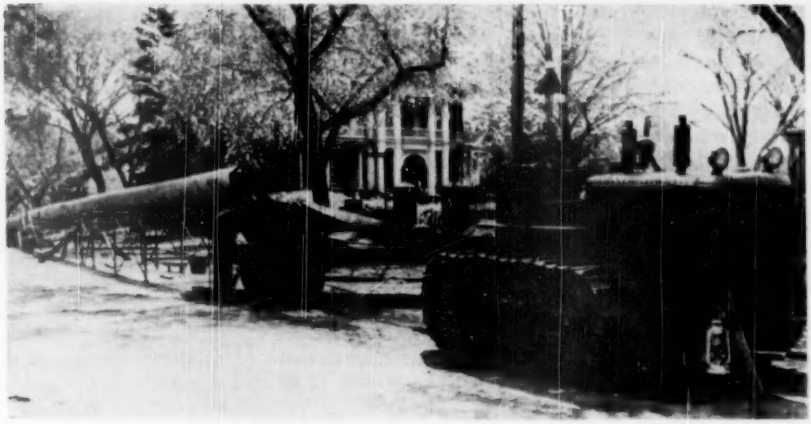

FIGURE 2.—Typical emergency sewage pumping installation.

such was the case in the Riverview district. Open manhole covers were bobbing up and down 3 to 4 in. due to the backpressure in the sewers.

A number of temporary pumping units were installed in some of the districts in an endeavor to regain control (see Figure 2). A 15-m.g.d. pump on loan from the City of Ottawa was installed on one district trunk sewer; a 7.5-m.g.d. pump from North Bay, Ontario, was installed on another. Several other pumps, ranging in capacity from 40,000 to 90,000 g.p.h., made up the estimated total capacity of approximately 65 m.g.d. The pump capacity presently under consideration by the Diking Board totals approximately 400 m.g.d.

Operation under Flood Conditions

As a result of flooding, seven of the nine sewage pumping stations within the city had to be closed down on May 6. Subsequent to this date, the flow levels in most of the sewers closely followed those of river elevations. Consequently, these sewers, the majority of which have been in the ground 40 or more years, were operating continuously for over three weeks under internal pressure heads ranging from 10 to 15 ft. Therefore, although only a relatively small portion of the city was actually inundated, the effects of the flood were felt in almost all parts of the city as a result of the sewers backing up.

Property Owners' Problems

The general problem confronting the majority of property owners was to prevent sewage from entering basements. In most cases, this was successfully accomplished by placing a 2-lb. charge of flaxseed sewn into a small cotton bag inside of the trap at the bottom of the basement drain. This was held in place with a substantial support braced to the ceiling. Rainwater pipes were disconnected so that the flow was diverted onto lawns. Considerable trouble was experienced from the accumulation of water in basements through the weeping drains. Many people resorted to pumping out this seepage, thereby aggravating the situation through the enlarging of underground channels.

People having toilet facilities in the basement had a much greater problem. It was necessary, in these cases, to remove the fixtures and plug the outlets. In some apartment blocks, flood valves had been previously installed on the main connections for the

purpose of preventing basement flooding during heavy storms. Although this method may be quite satisfactory for storms, which are usually of relatively short duration, it imposes a considerable problem during flood conditions lasting several weeks. A number of these premises were without normal sanitary facilities for this reason. It would be advisable, in such cases, to connect all basement fixtures to a separate branch protected by a flood valve so that, under flood conditions, only the basement facilities would be out of service.

A great deal of trouble was experienced in the downtown area through excessive seepage entering the basements. The main shopping area sounded more like the center of a large construction project than just a busy street corner. The noise of the many pumps operating day and night, discharging their incessant streams out into the streets, could be heard for several blocks.

Sewer connections which had long been out of service suddenly became evident—with devastating effects. In one instance, a section of the concrete floor in the basement of a large office building burst open, flooding the premises. The owners succeeded in controlling the flow with several hundred sandbags, but the odor in the basement left no doubt as to where it originated. In Winnipeg, the entire length of the sewer connection is the responsibility of the owner. Although the Sewer Department endeavors to keep a close check on the cutting out and plugging of unrequired sewer connections, there are still many which, over the years, were never recorded. If there is one lesson that can be learned as a result of the flood, it is the necessity of having adequate up-to-date records of the sewer system.

The maintenance staff of one of the large department stores was confronted with a very difficult problem. Seepage through the lower courses of the basement walls, constructed of stone masonry, was not very great; it was, however, highly concentrated sewage. This seepage extended around almost one-third of the wall perimeter; a considerable distance, as the store fronts on a full city block. The only explanation that can be given for this condition is the unavoidable leakage of the sewer system operating under pressure. Under these conditions, there is little flow in the sewers and each day the sewage becomes more concentrated.

These are but a few of the problems that confronted property owners as a result of flooded sewers.

Potential Contamination of Water Supply

The citizens of Winnipeg were very fortunate in that, throughout the emergency, there was no outbreak of diseases to add to the many inconveniences that were being endured. Everyone is aware of the importance that must be attached to the water supply even under normal conditions, for there is no greater medium for the spread of disease. The potential hazard can be appreciated when it is realized that in Winnipeg more than 300 mi. of water service pipe lie adjacent to and in close proximity with corresponding lengths of sewers and house connections. The water distribution system lies at a depth of 8 ft. below the surface in a soil particularly active, both chemically and physically. The sewer system, for the most part, lies below the elevation of the water mains. During 1949, 314 water main breaks were recorded. Of this total, approximately 40 per cent was attributable to corrosion, 39 per cent to excess stresses caused by movement of the soil, and 21 per cent to other causes. During the first three months of 1950, 95 main breaks were recorded, as compared to 68 during the same period of 1949, an increase of approximately 40 per cent. From April 17 to June 24, during which period the Red River was above

the 10-ft. level, 45 main breaks became evident. It should be apparent, therefore, that the water distribution system required a very considerable amount of maintenance during the tenure of the flood.

An unusual situation was encountered with the repair of one water main, on which five separate breaks were repaired between May 19 and May 27. No sooner was one repair completed, the main sterilized, and returned to service, than another break was reported. The condition of the pipe indicated that excessive corrosion had taken place during the 46 years the main was in service. It is believed that the soil surrounding the pipe had become saturated, thus reducing the restraining effect to such an extent on those portions of the main graphitized as a result of galvanic corrosion, that the pipe was unable to withstand normal pressures. This would indicate that leakage from sewers operating under pressure for a considerable period may be very substantial, particularly if there exists a root-clogged and cracked condition of the trunk sewers such as is shown in Figure 3.

Recalling, also, the experience mentioned under "Property Owners' Problems," it should not be difficult to visualize the water mains throughout the entire city being, more or less, surrounded by ground water contaminated directly by sewage. If, for some

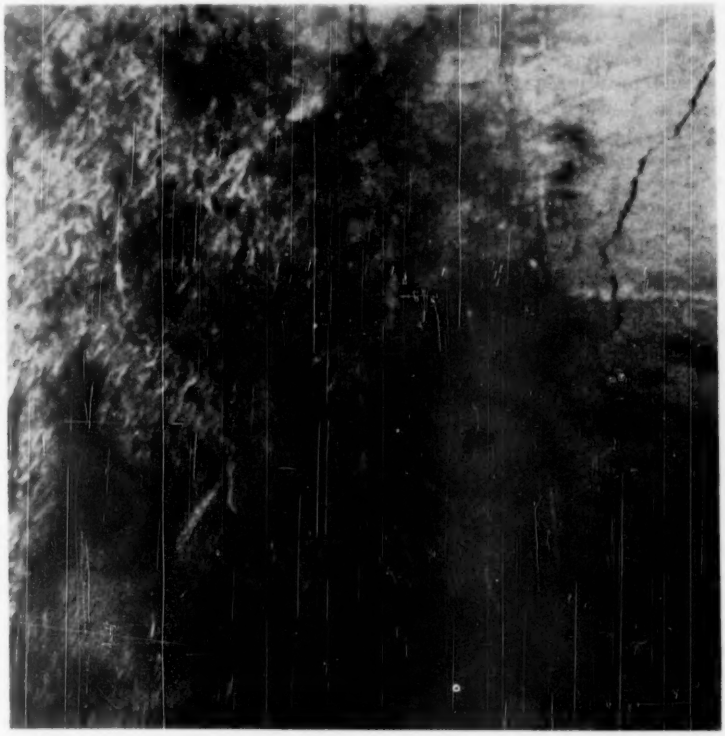

FIGURE 3.—Tree root growth and crack in crown of trunk sewer (photograph taken prior to flood).

reason, the pressure within the water distribution system should be allowed to drop below that of the hydrostatic pressure of the contaminated water surrounding the main, then wherever there was a break in the system, back siphonage would be inevitable. This condition was avoided by operating part of the water pumping station on stand-by power. Thus, if normal power failed, there would still be a limited pressure maintained on the water system. As a further precaution, the chlorine content in the water supply was increased from 7 lb. to 22 lb. per m.g.

Owing to the precarious situation which existed with respect to the flooding of two terminal substations, a 297-kw. diesel-electric stand-by plant was provided at the main pumping station.

Another condition leading to potential contamination of the water supply is that in Winnipeg the hydrants are drained through sewer connections. Under flood conditions, these drains constitute a potential cross connection between the systems. Extreme care was exercised that hydrants were not used to release pressure from or to drain a section of water main. Considering the extent of the systems and the duration of the flood, it is quite reasonable to assume that the possibility of contamination was potentially great.

Flooding of Underground Services

All utilities having underground services were faced with the formidable problem of endeavoring to maintain their facilities in service under flooded conditions. In many parts of the city, maintenance crews of the Manitoba Telephone System could be seen pumping out cable ducts in order to prevent a breakdown of communications. There is no need to amplify the absolute necessity of maintaining communications during a crisis of the magnitude that was experienced in Winnipeg this spring. The Police and Fire Departments' communication facilities were also seriously affected. Provision of stand-by communications to vital points was given urgent attention and mobile emergency communications were extensively used. The Water Works Division established and maintained communications to the various diking areas within the city. A total of 22 radio-equipped vehicles were maintained almost continually on flood communications. In the three or four days subsequent to May 5, the volume of traffic cleared through this channel was beyond conception.

Steam heat was shut off in the downtown area on May 3 as a result of flooding in the steam heat ducts. Power companies were confronted with many service problems; a good many cases of flooding of the underground services resulted from the flooded conditions present in the sewer system.

Influence on Transportation

Transportation in a large city presents a considerable problem, even under normal conditions. It becomes of major concern under emergency conditions, particularly when use is denied of several river bridges and the majority of railroad underpasses.

There were 12 underpasses within the city flooded as a direct result of the flooded conditions present in the sewer system. By-passes were constructed over the Canadian National Railway mainline tracks at two places. An endeavor was made to pump out the sewers in one district so that four other underpasses could be re-opened. However, it was not possible to isolate this district sufficiently from flood waters to effect any change in the level of flow in these underpasses until the river had receded. The reason for re-opening the underpasses will be readily appreciated when it is considered that the city yards, located between several of the five railways serving the city, was a main supply point for the materials used in fighting the flood.

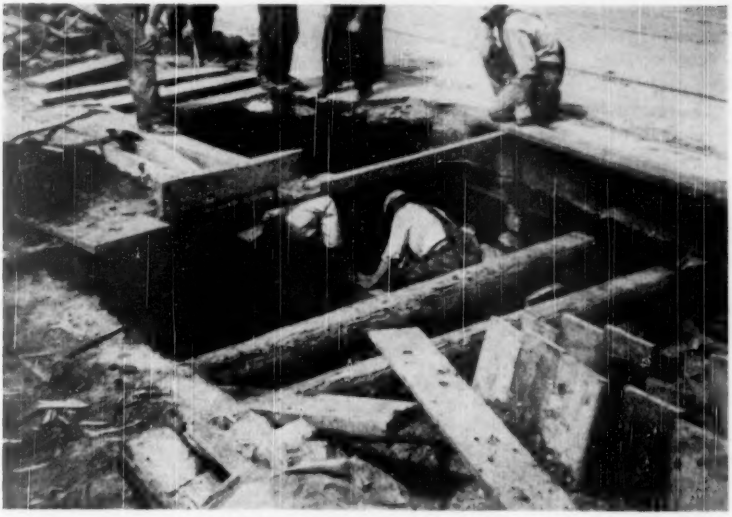

FIGURE 4.—Cave-in at major street intersection caused by backwater pressure bursting sewer and washing away fill.

Much effort was directed towards reopening another underpass to make use of a second bridge connection with communities across the river. This underpass was pumped out sufficiently to allow truck and bus traffic to use the bridge for a period of three or four days, at which time it was allowed to fill up again because of apparent damage to the abutments.

At approximately 9 A.M. on May 11, a report was received that water was coming through a crack in the pavement about halfway down the north approach of one underpass. At first, this was considered to be a water leak, until it was realized that there was no main within several hundred feet of the location. The leak was attributed to a 6-ft. sewer located near the underpass. By that evening, the underpass was filled with several feet of water. On that date, the elevation of the river adjacent to this location was approximately 32 ft.; as the elevation of the top of the trunk sewer at the underpass is 13 ft., it can be assumed that the sewer was subjected to an internal head of approximately 20 ft. when flooding of the underpass took place.

Maintenance of Sewer System

In general, the maintenance required as a result of the 1950 flood has been somewhat less than was first anticipated. Up until August 23, 75 sewer cave-ins were recorded. Of these, 52 were repaired at a total cost of approximately $13,000, or an average of $250 per repair. In addition, a repair on Main Street at River Avenue, between the Red and the Assiniboine Rivers, cost approximately $11,400, or almost as much as the total cost of the other 52 cave-ins (see Figure 4).

It has been evident from the repairs completed that several of the sewers will require cleaning. To date, 6,000 of an estimated total of 10,500 catch basins have been cleaned at an average cost of $2.40 per basin. Catch basins in the inundated areas were, on the average, filled with sludge to a depth of 2 ft. above the hoods. In some cases, they were filled to street level. The

work of liberating stoppages in the sewers and catch basin connections has been considerable.

During the flood, inquiries were sent to several of the larger cities to determine what sewer cleaning equipment might be made available should it be required. The response was very gratifying. However, it was not necessary to bring in any of this equipment except two catch basin cleaning units made available by Toronto, Ontario.

The full extent of the damage to the sewer system will not be known until an inspection of the sewer outlets and the trunk sewers can be carried out.

EAST LANSING'S AUTOMATIC SEWAGE SAMPLERS

By Maurice S. Richmond

Superintendent, Water and Sewage Dept., East Lansing, Mich.

Upon the completion, in 1949, of the 1.8-m.g.d. addition to the original 1.5-m.g.d. sewage treatment plant at East Lansing, Mich., the writer revised the plant operating reports, in an attempt to present a more complete and accurate picture of the sewage treatment operation. It was apparent, immediately, that the method being used for compositing samples was far from desirable. With operators in attendance only 10 hr. per day, the sewage flow was left unsampled during the remaining 14 hr. of each day.

To purchase commercial sampling devices was out of the question financially. It appeared that the only alternative was to make sampling units, if the plant was to have them at all. Therefore, Gordon Stafford, one of the plant operators, was detailed to the task of experimenting with various types of units. After building some five or six different types of samplers, it finally was decided to use the type of machine shown in Figure 1.

The machine operates on the water wheel principle and can be used to collect samples of liquids in any channel where the flow velocity is sufficient to rotate the paddle wheel. The paddles are fastened to spokes of brass tubing (D) with sample-collecting openings in the outer ends. As the spokes rise, the sample flows into the hollow conical-shaped hub (E) and on into the outer hollow hub (B). Except for every seventy-second revolution of the paddle wheel, the samples flow through hub B and drop back into the channel.

On the seventy-second revolution of the paddle wheel, the sample drops into the collecting jar (F) as a result of the following sequence of events. A key in the end of the paddle wheel axle shaft turns the cogs in wheel A. On each revolution of wheel A another eccentric cog on the side of the wheel raises rod C, which in turn temporarily stops the rotation of hub B. The stoppage of rotation of hub B allows a hole in the hub to line up vertically with another in hub E, thus allowing the sample to drop to the jar, rather than run on out the end of hub B, as in the case during the other seventy-one revolutions of the paddle wheel.

As the speed with which the paddle wheel turns is in proportion to the flow velocity, the machine samples fairly well in proportion to the quantity of flow. The flow of sewage through the spokes and hubs keeps the machine from becoming coated with ice in the winter time. In addition, this same sewage flow through the machine parts has kept them free from any filamentous growths, even in the warmest summer weather.

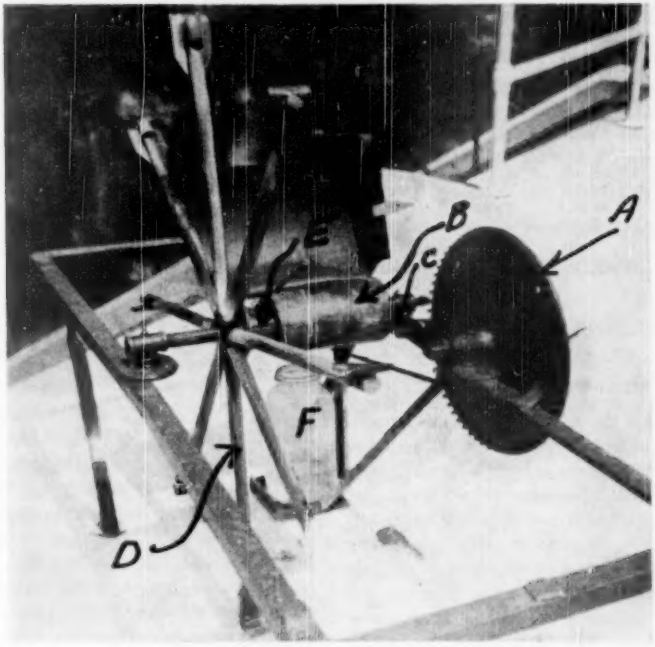

FIGURE 1.—Simple shop-made machine automatically collects composite sample proportionate to flow.

The several sampling machines of this type in use at the East Lansing sewage treatment plant have been in constant service for more than six months. They have required a negligible amount of maintenance and were built at a cost of approximately $3.00 each, plus spare-time labor.

INTERESTING EXTRACTS FROM OPERATION REPORTS

Attention operators! It will be appreciated if copies of all annual reports of both large and small plants are sent to the Federation office for abstracting in this section of the Journal. Carbon copies of typewritten reports will be promptly returned on request. Please direct annual reports to: Federation of Sewage and Industrial Wastes Associations, Room 325, Illinois Bldg., Champaign, Ill.

Annual Report of the Buffalo Sewer Authority for the Year Ending June 30, 1949 [1, 2]

JOHN W. JOHNSON, *Works Superintendent* [3]; GEORGE F. FYNN, *Chief Chemist*; AND CECIL F. SEITZ, *Chief Engineer, Sewers Dept.*

Inlet Well and Screens

Flow in the plant inlet wells at discharge ends of the harbor crossing tubes is controlled by electrically operated switchgear on three 96-in. by 96-in. sluice gates. Accumulative effect of grit in contact with the lifting screws of these gates caused fouling of the engaging threads so that one became inoperative this year. It was possible to have this 18-ft. long, 3.5-in. diameter bronze stem remachined for less than one-half the cost of a new replacement.

The screenings grinders, fed by belt conveyor from the mechanically-cleaned bar screens, were not used this year except to test experimental cutting teeth. The total quantity of screenings removed and buried was 1,287,800 lb. dry weight.

Chlorination

Chlorination is continuous through the year to provide a sterilized effluent. Average daily dosage this year amounted to 4,270 lb., which because of low flows was less than the 11-year average of 4,720 lb. Contact period is provided in the sedimentation tanks.

For some years, one operator has been assigned three days per week to maintenance of the chlorination equipment. This has paid, because there have been no serious breaks in the service lines and all five units are usually ready for service. Many intricate fittings and parts have been reproduced in the plant shop and although the price of chlorine has doubled in the last 10 years, no major replacements to equipment (five 6,000-lb. per day machines) have added to the cost of this item of treatment.

Sludge Handling

Settlement of the sludge suction line from one tank continued to plague the department during times of storm because of the impossibility of keeping the pipe free from sand and other materials. Action was taken at the end of the current fiscal year to have this line relaid. Change in method of removing condensation water from the oil reservoir of sludge removal mechanisms has improved conditions so that no replacements to drive or gears were necessary during the year.

Because of the gritty consistency of the sludge, packing of pumps continued to be a major item of maintenance. It was necessary to provide new pistons for several raw sludge pumps.

Plugged suction lines have been the source of most difficulty in operation of this station. New connections to provide increased capacity to all tanks were installed during the year. Suc-

[1] For last previous extract see *Sewage Works Journal*, **20**, 4, 740 (July, 1948).

[2] Recipient of FSWA 1950 Hatfield Award for plants serving over 100,000 population.

[3] Presently general manager.

tion flow of tank skimmings or scum was segregated from the line conveying raw sludge, but a separate discharge line could not at present be considered. The alternate is storage or disposal of this material at or near the collection point.

To improve digestion, four heat exchanger units of the hot-water and sludge-tube type were installed this year, together with four vertical centrifugal circulating pumps. This equipment replaces badly deteriorated heating coils within the digesters and "drafted" centrifugals which were used for circulating service.

Circulating pump disorders have brought out these facts:

1. Water seals are required with automatic shut-off control.

2. Bronze guide sleeves are unsatisfactory. Stainless steel also wore out. Hard chrome-plated bronze tubes are now in service, but the consensus is for more flexible wearing faces. Rubber is planned on the next replacement.

3. Raw sludge circulating requires that particle sizes be reduced to a minimum to eliminate tedious and messy cleaning of clogged pumps.

4. Pumps and lines must be kept entirely free from putrescible substances during any period of shutdown, as digestion and generation of gas will burst gaskets and cause leaks within the system.

5. A packing is needed which will be satisfactory under the gritty and greasy conditions which develop.

The problem of prolonging life of the filtering medium, canton flannel cloth, continued to receive attention from the operating, maintenance, and laboratory divisions. Physical characteristics of material have had much to do with results. The same type of cleaning has failed to give any uniformity in length of service, even though a set strength of acid and time of washing and flushing was maintained. Service from a blanket made up of nylon fibers having a nap or fibrous surface was spasmodic. Because of high first cost, no conclusions can be drawn until a minimum of service hours has been reached.

There was substantial reduction in the amount of conditioning chemical dosage for this year, as rates were the second lowest in 11 years. This has been fortunate, considering the high cost of lime and the increase in cost of ferric chloride.

Being unable to burn sludge cake because of reconstruction of a belt conveyor and modernization of one of the incinerators, load in the digesters reached an all-time high and it was necessary to resort to dumping as fill. During a two-month period it was possible to dispose of nearly 9,500 tons of cake by hauling from dawn to dark. Load reduction thus effected, plus the restoration of bacterial activity within the digesters, made possible in the final inventory a reduction of over 3,300,000 lb. of dry solids.

Laboratory

The laboratory staff undertook 6,643 analyses during the year, which included 3,144 sanitary chemical, 3,121 bacteriological of sewage and water, 119 ferric chloride, 109 lime, 11 oil, 8 aluminum chloride, 27 physical, 21 gas, and 83 miscellaneous chemical analyses. Of the total enumerated, 6,305 samples were collected from various units of the plant.

Exclusive of plant samples there were collected for inspection and analyses 40 samples from Niagara River, 37 from Buffalo River, 247 from materials received, 7 industrial waste discharges, and 7 from sewers. For analyses of samples designated in the previous tabulation, 41,947 tests were made, including 8,578 chlorine demand determinations on the raw sewage and tank effluent.

Investigation of various aspects of sludge conditioning was continued to improve chemical dosage. Temporary

troughs for flash conditioning were installed, with excellent results. Instead of dosing the entire contents of the conditioning tank, chemicals were added to the sludge just previous to its passage to the filter tub. Water additions, experiments in changing point of introduction of chemicals, and drum revolutions were studied as part of the program.

Temperature conditions within the dosage tub showed tank sludge to be approximately 95° F., with an increase to 102° F. after lime slurry additions at 124° F., and a decline to 96° F. prior to filtration.

Consideration of a possible substitute for ferric chloride led to several experimental runs using an industrial waste discharge containing approximately 20 per cent aluminum chloride by weight. Results indicated consumption practically equivalent to ferric chloride on poundage, although vapor formation presented a problem. The uncertainty of a steady supply of this material precluded the possibility of a present change to use of this material.

Samples of various types of filter cloths were tested in the laboratory. Plant tests were made on a nylon and vinyon type cloth, but final information on results must be projected into next year. Tests on used cloth to determine possible reasons for failure showed contents of 2.35 per cent inert material, 2.15 per cent iron oxide and 30.05 per cent lime.

Studies were made on alkalinity content of filtrate samples as a proposed basis for conditioning control, but extreme variations in results did not furnish a reliable basis for practical use.

Quarry Project

A substantial amount of the contract work was accomplished during the year on a project to utilize an abandoned quarry for storm-water relief in the Kensington area. The temporary storage afforded by the basin will greatly relieve trunk main capacity at times of storm flow, for later return to the

TABLE I.—Summary of 1948–49 Operating Data, Buffalo, N. Y.

Item	Average
Estimated population served	620,000
Equivalent population	920,000
Sewage flow (m.g.d.)	135
Grit removed (cu. ft. per m.g.)	3.1
Laboratory analyses:	
pH raw sewage	7.4
Suspended solids:	
Raw (p.p.m.)	200
Final (p.p.m.)	116
Per cent reduction	42.1
B.O.D.:	
Raw (p.p.m.)	120
Final (p.p.m.)	87
Per cent reduction	27.3
Chlorine demand:	
Raw (p.p.m.)	4.7
Supernatant liquor (p.p.m.)	757
Over-all total (p.p.m.)	5.42
Presumptive coliform bacteria:	
Raw (1,000 per ml.)	97.9
Effluent (1,000 per ml.)	2.74
Raw sludge:	
1,000 gal. daily	126
Per cent dry solids	7.4
Per cent volatile solids	65.9
Digested sludge:	
1,000 gal. daily	64
Per cent dry solids	9.6
Per cent volatile matter	61.7
Supernatant liquor:	
1,000 gal. daily	128
Per cent dry solids	3.0
Per cent volatile matter	56.3
Digestion tank operation:	
Temperature (° F.)	85.5
Sludge gas:	
CO_2 (per cent)	39.6
CH_4 (per cent)	57.0
B.t.u. per cu. ft.	570
Cu. ft. per capita	0.65
Cu. ft. per lb. vol. matter added	7.3
Incineration:	
Tons wet sludge cake daily	85
Pounds wet cake load per furnace hour	5,424
Per cent lime (dry basis)	8.84
Per cent ferric chloride (dry basis)	2.43
Cu. ft. gas used per lb. sludge burned	1.32
Costs ($ per m.g. treated):	
Pumping	2.37
General treatment	3.83
Digestion	1.10
Filtration	1.59
Incineration	2.87
Total	11.76

treatment system. The cost of the project when completed will be approximately $2,000,000, including the necessary connecting sewers and pumping station.

Sewers

Complaints of sewer trouble have increased slightly during the past year to a total of 932 as compared with 878 in the previous year and 762 in the next preceding year. As has been customary, a large proportion of complaints have been found upon investigation to be due to lateral connections or other sources of trouble outside the jurisdiction of the Authority. It has been necessary to clean sewers in but 220 instances out of 932 complaints. In addition to the foregoing, a total of 591 sewers has been inspected during the year; 371 have been cleaned as a result thereof and 220 have been found not to require cleaning.

Table I is a summary of the 1948–49 data.

THE DAILY LOG

Aurora, Illinois

By Walter A. Sperry, *Superintendent*

May 8—The diary entry for yesterday, Sunday, was a little premature with its optimistic "Out for routine check-up. All normal at the plant." Apparently we did not reckon sufficiently with the teen-age boy's capacity for mischief, as our arrival this morning was greeted by a tale of woe from the late-shift operator. Three or four boys had asked and were given permission to look about the plant. This often happens and, generally, they are well behaved after a warning not to ride the clarifier bridges. However, about 4 o'clock, when the operator went to the river to collect the routine filtered and secondary tank samples, he made a disturbing discovery; the boys had climbed up the 6-ft. side walls to the top of the stone filter beds and had kicked off about 40 filter nozzle heads. No reason can be ascribed to this wanton act, unless they were fascinated by the ease with which the brass castings snapped when they kicked them. Replacement cost, new, would have been about $100. However, the broken heads were brazed, rethreaded, and nutted for considerably less. This is the first time we've had this type of trouble, and certainly hope it's the last!

May 10—More of boyhood's summertime mischief. This afternoon two District employees reported the results of investigating a tip that manholes were being tampered with in a remote section of one of our interceptors. From one manhole, eleven large boulders were taken; from a second, three boulders and an armful of horseweed. A third was completely filled with a mixture of boulders, planks, tin cans, shingles, bottles, old concrete, etc.

The manholes in this area have been discussed before. After finding a playhouse built in one, we had sealed some 15 manhole covers with hot asphalt. As a result of today's experience we can report that this plan was not too successful. Some better seal or lock must be devised. However, closing the finger hole should be effective, as then it would take a slender-bladed tool (spring leaf?) to raise the cover. The solution is not yet apparent, but we are thinking over the idea of welding

the finger hole shut, then drilling and tapping two holes near the outer edge of the cover. The holes might be closed with brass studs screwed tight. To open, the brass studs would be removed and eyebolts substituted, so that the cover could be lifted by a bar through the eyes.

May 15—Previous tampering with the same manholes finally hit us in a particularly vulnerable spot—the siphon on this same interceptor under the river. The unusual rains this spring resulted in overflows indicative of a plugged siphon. When flows subsided, the upper pipe (16-in. diameter) was found effectively dammed by a jam of 2×6 timbers. From the lower pipe (10-in. diameter, for dry weather flow) there was removed a 4-in. diameter tree limb 8 ft. long and a chunk of concrete measuring $29 \times 9 \times 7$ in. and weighing 32 lb. (see Figure 1). The piece of concrete so nearly filled the 10-in. pipe that the heavy sewer rods actually grooved it. A scale drawing failed to show how the tree limb could get from the diversion chamber into the 10-in. pipe, let alone pass through the several elbows in the siphon.

FIGURE 1.—The reasons the 10-in. siphon pipe was plugged.

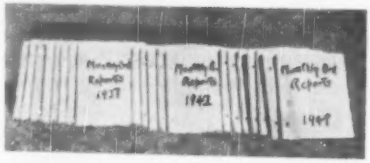

FIGURE 2.—Bound copies of monthly reports are second step in permanent plant records.

May 20—As pointed out in a previous Log, the plant diary is the fundamental starting point of the administrative side of record keeping. The next step is the Monthly Board Meeting Report. At Aurora, a copy of this report, signed by the superintendent, lies on the table before each trustee and officer at each meeting. Its form and sequence follow a standard pattern throughout the 10 pages, divided as follows: two pages listing all bills and their requisitions for which checks have been prepared, three or four pages containing the superintendent's comments on all important happenings and needs, one page of plant removals data, one of cost data, one of laboratory results, and one of cumulative quantitative data.

The monthly reports are of excellent value, as (1) they completely summarize each month while the circumstances are fresh in mind, (2) they are a valuable accumulating source of information, (3) they constitute one of the main sources from which the annual report material is compiled, (4) they keep the trustees informed of District affairs, and (5) they do away with lengthy verbal reports and the strain of struggling to get attention for this or that item. Bound in standard folders by years (Figure 2), they are a valuable plant operation record and are kept in the office safe.

June 1—A previous Log (see THIS JOURNAL, **22**, 8, 1077; Aug., 1950), under date of March 2, gave Eagle, Pa., as the address of a company manufacturing a concrete water-sealing compound. Actually, the company is located in New Eagle, Pa.

June 15—A glum set of officers as a result of the June Board meeting. For five years, plans have been under way to rehabilitate the main building group, including enlarging the office and laboratory; a general storage room for oils, paints, and supplies; a record storage room; a new clarifier house, complete with new walls and roof; and air conditioning for the laboratory, where temperatures are often above 90° due to the engines in the adjoining room. If bids were favorable, the plans included a classroom for high school students and nurses. Plans are to abandon the present stucco-type structures and replace them with vitrified brick and glass block windows that would last for 100 years, instead of 20.

In June, no bids—the contractors were too busy. (In September there was one bid, but much too high—$160,000 with an escalator clause that made it impossible.) We hope to try again in January, when the contractors will be looking for new work.

June 21—While planning for the main building group we had better luck with the digester and screen house structures. The digester house walls are of cement, about 2 in. thick, plastered to a core of metal lath. These walls were not in bad shape, but the water table was badly cracked and spalled after 20 years. The screen house is a brick structure plastered with 1-in. thick stucco, 25 or 30 per cent of which had cracked, or loosened, or fallen off. Both buildings looked unsightly. Now that the exterior of both these buildings has been treated with a process known as "colorcrete" there is reason to believe they will not need maintenance again for 10 years or more. Colorcrete consists of an application of a high-grade waterproof Portland cement to a wetted surface with a hand gunite machine that shoots the mortar onto the surface under a spray pressure of 18 p.s.i. The coating thus applied is about ¼ in. thick and completely seals and waterproofs the wall. It is cured for a day or so after application with a water spray. Buildings in Aurora so treated 10 and 14 years ago were found to be still in excellent condition. This service was bought for $0.20 per sq. ft. for a two-coat job on the screen house and $0.12 per sq. ft. for a one-coat job on the digester house. Total cost for both was $1,125. The toughest job was the stripping of the old stucco from the screen house. Provokingly enough, although some of it fell off, about 40 per cent had to be chipped off in small pieces using a medium-weight crowbar and working downward from scaffolds.

June 23—Today the gas engine exhaust line broke in two at a cast-iron tee connection. During some alterations to the line last year, a flange connection was brazed onto the tee at this point. The boss welder gave one of his men a good combing for this. As he later explained, one does not braze cast iron safely under a combined condition of stress and temperature. Now the tee has been permanently replaced with a steel one made up of welded flanges and 4-in. steel pipe.

July 1—Your Logger takes some pride in passing along the suggestion that at the appropriate time an affair similar to one recently held in Aurora be staged in your community. In what proved to be a most happy public relations endeavor, the Aurora Kiwanis Club held a 25th Anniversary Dinner in honor of the trustees and officers of the Aurora Sanitary District. Attending were all the District trustees and

officers, including the County Judge (who appoints the trustees); high officialdom of the city, including the mayor; the president and secretary of the Chamber of Commerce; the editor of the local newspaper; and the presidents of the other five luncheon clubs, the Aurora Woman's Club, and the Business and Professional Woman's Club. Short informational talks were made by the District's attorney, engineer, and superintendent, after which the several special guests made appropriate responses. The Aurora "Beacon-News," in two issues, covered the event with two 5 × 8 pictures, 31 in. of double-column editorials, and 52 in. of text. The pulse of the affair might well be gathered from the following, taken from one of the editorials: "It was agreed that the accomplishments of the District rate with the top works for public good in the 113 years of Aurora history."

TIPS AND QUIPS

Local and "National" Praise

Two recent issues of the Webster City, Iowa, local newspaper carried articles praising the superintendent of the Webster City sewage treatment plant. Indicative of the high esteem with which he is held by his fellow townsmen, is the newspaper's appraisal that "one of the most important jobs in Webster City belongs to Leo Holtkamp, superintendent of the sewage works." The article goes on to say that Holtkamp is also secretary of the Iowa Sewage Works Association and one of the first men in this country to receive a diploma for sewage plant operators from the International Correspondence Schools.

The second item concerns a letter received by the city manager thanking the city, and especially Holtkamp, for the fine cooperation and assistance extended while a U.S.P.H.S. group made a recent operation study of the Webster City sewage treatment plant. The plant was selected for the study because of the two-stage filtration features of its design.

Another case of good work being appreciated!

Relief Valves for Pumping Systems

In a discussion of the causes and avoidance of relief valve "chatter," W. F. Braun, of the J. E. Lonergan Company, Philadelphia, Pa. (*Meters and Controls*, **12**, No. 4; July–Aug., 1950), presents the following useful check list for diagnosing and treating the ailment:

1. Valve oversized. Ordinarily, this is simply a problem of careful sizing of valve in proportion to flow. However, a condition of relative oversizing may result from an inadequate or "starved" entrance condition (as when the valve is mounted on a long or undersized line resulting in pressure drop under the valve). The best approach is always to correct the piping or inlet condition. When this is impracticable, a parabolic orifice relief valve of adequate size may be used.

2. By-pass applications. This condition may be met by using two relief valves, one sized to carry normal by-pass flow; the other, set at a somewhat higher pressure, to cut in when total pump load must be carried. Alternatively, a parabolic orifice valve of adequate size may be used.

3. Outlet piping inadequate. Never reduce outlet piping below the outlet size of the relief valve. If a long outlet is required, increase the size of the outlet piping.

4. Valve set pressure too close to operating pressure. Set relief valves 20

to 25 per cent above operating pressure for best results.

5. Type of valve not suited to application. For example, where a "pop"-type (vapor or gas relief) valve is used instead of a hydraulic-type relief valve, without compensating ring adjustments. (Control ring should be backed away to inoperative position when pop valve is used for liquids.)

6. System subject to harmonic overpressures. Sometimes this condition is encountered on high-pressure systems. An air column in the system helps to compensate for this. Special valves are indicated.

Odds and Ends

In his annual report for 1949, Walter A. Sperry, superintendent of the Aurora (Ill.) Sanitary District, mentions several small but important items of maintenance. Among those worthy of note by other operators are the following:

1. The doors of the secondary pump house were armored on the lower panels with galvanized iron as a protection against rats.

2. A cupboard was constructed in the engine room for storage of tools and engine parts, greatly facilitating the labor of maintaining the engines and generators.

3. The sludge meter room, always a problem to maintain in an attractive, presentable condition, was completely refinished with "Damptex," a rubber-base paint useable on damp surfaces and in places where the walls may be frosted or sweated. Painting the floor with rubber-base paint so improved the appearance of the room that it had a direct psychological effect on the operators in maintaining it in a presentable condition. The effect was akin to the custom of painting stairway corners white against the tendency of men to foul them with tobacco juice!

4. Undoubtedly one of the most useful improvements of the year was the cutting of a drain into the storm sewer system at the entrance to the screen house. At this point the sidewalk was low and storm water constantly accumulated, requiring planks to bridge it.

Incidentally, the mystery of such simple improvements, in Mr. Sperry's own words, is: "Why the long delay in making them?"

Something New in Valve Packing

A new V-ring type valve and hydraulic packing molded from pure Teflon is claimed by the manufacturer to combine the chemically inert and frictionless properties of Teflon with the resilience and toughness needed for proper sealing results. The special cross-section design (Figure 1) insures permanent sealing, even under varying pressures, at temperatures up to 450° F.

Although only recently introduced, the new packing has already been adopted by several leading manufacturers as a standard part of their valves. The packing is claimed to

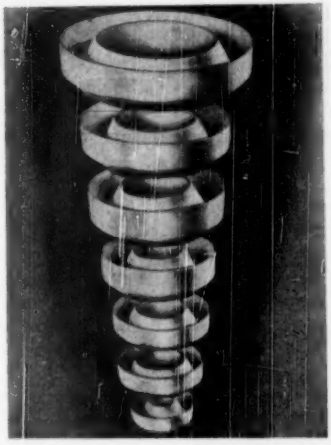

FIGURE 1.—New frictionless, chemically-inert V-ring valve packing.

stand up several times longer than conventional packings previously used, to form a perfect seal with just finger-tight pressure on the gland, and to eliminate the destructive wear on hydraulic valve parts.

The new packing, together with packings of the same material in presently used shapes, is described in a free booklet, "Packings for the Chemical Industry," available from the Crane Packing Company, Dept. R-7, 1800 Cuyler Ave., Chicago 13, Ill.

Easy on City's Pocketbook

A painless method of financing a municipal sewage treatment plant has been found by the city of St. Ann, a suburb of St. Louis, Mo. A subdivision developer, having built a plant to handle sewage disposal for four residential subdivisions, turned the plant over to the city. According to the St. Louis County Health Department, the $135,000 plant is one of the best in the state!

Nipple Chuck

A new chuck for the threading of short nipples is announced by The Ridge Tool Company, Elyria, Ohio. This Ridgid nipple chuck is of simple design and fits any threading machine or vise without special tools, parts, or adjustments, according to the manufacturer. It requires no adjusting or changing of the stop plug, which is an integral part of the nipple chuck and is said to be always automatically in position for use. Nipples to be threaded are screwed in by hand; after threading, they are released instantly by an easy turn of the chuck, so they can be unscrewed by hand. Pipe adapters are made for all sizes of pipe from ⅛ in. to 1½ in.; the nipple chuck itself holds 2-in. pipe. The device also is made for British Standard pipe thread.

"Hot" Mosquitoes

Recent announcement that 1,000,000 radioactive mosquitoes have been released in a 10-mile irrigated pasture at Turlock, Calif., is enough to set one back on his heels—and with a really stiff jolt! Having spent millions of dollars on eradicating the pestiferous disease bearer, the current program seems incongruous. At first glance, it would appear that we've equipped the little buzzers with another lethal weapon in their war on mankind.

However, it's all in the interests of science. By using radiation detection devices of various types, scientists will be able to delve further into the life, flight, and habits of mosquitoes, on whose control California alone is now spending $2,000,000 per year.

We wonder if the sting of an activated mosquito is any more painful or annoying than normal. Imagine—an airborne "hot foot"!

Editorial

THE TWENTY-YEAR INDEX

To those who had the onerous responsibility for its production, the enthusiastic reception being given the new Twenty-Year Index to *Sewage Works Journal* is highly gratifying. The demand is now approaching 1,000 copies, but even more satisfying have been the numerous favorable comments received from users of the Index. These have more than justified the labor and time expended in the project.

The writer, who planned the content, style, and format of the Index, is both pleased and relieved to find that its several unorthodox features are being received with favor. Every detail was designed to assist the searcher in locating the reference sought in a minimum of time, which made it necessary to sacrifice a number of time-honored conventions. The end result has been a compact key to a wealth of technical information and data.

Several purchasers of the book, who initially considered it only a source for historical references, have expressed astonishment at the amount of material contained in the early volumes of the *Journal* that is of permanent usefulness. In this respect the writer was actually grateful for the opportunity to delve back through the 115 issues that comprise the first 20 volumes, as a means of refreshing his memory on significant work in the past two decades. The same sentiment was voiced by Dr. G. E. Symons in the course of his work on the Index.

It was Dr. Symons, incidentally, who undertook the enormous chore of assembling the subject index into its preliminary form. This was a job of many months duration, for which the remuneration given Dr. Symons was modest indeed. His personal contribution to the Index, was, therefore, a substantial one.

It is intended that cumulative indexes to the Federation's *Journal* will be produced for every ten volumes in the future, which would make the next one due upon the completion of Volume XXX in 1958. In this way the reference value of the *Journal* will be maintained indefinitely, and it will obviously be advantageous to readers of the *Journal* to keep and bind their copies for continuing reference.

More than a thousand copies of the Twenty-Year Index are still on hand in the warehouse of the printing plant, where they are serving no useful purpose. Those who have not yet secured a copy are urged to do so without delay. The book will pay for itself many times over in time saved during the first year of its use.

As is the policy on all special publications of the Federation, the Index venture is intended to be self-supporting, but not a source of operating revenue. Any surplus of receipts over costs will be credited to the Manual of Practice Revolving Fund.

W. H. W.

MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Time*
New York Sewage and Industrial Wastes Association	Hotel Statler, New York, N. Y.	Jan. 19–20, 1951
Texas Water, Sewage and Industrial Waste Association	Texas A. & M., College Station, Tex.	Mar. 11–15, 1951
New Jersey Sewage and Industrial Wastes Association	Haddon Hall Hotel, Atlantic City, N. J.	Mar. 14–16, 1951
Louisiana Conference on Water Supply and Sewerage	Louisiana State University, Baton Rouge, La.	Mar. 21–23, 1951
Arizona Sewage and Water Works Association	El Tovar Hotel, Grand Canyon, Ariz.	Mar. 28–30, 1951
Virginia Industrial Wastes and Sewage Works Association	Hotel Chamberlin, Old Point Comfort, Va.	Apr. 5–6, 1951
Arkansas Water and Sewage Conference	Hot Springs, Ark.	Apr. 9–11, 1951
Kansas Sewage Works Association	Lamer Hotel, Hays, Kans.	Apr. 11–13, 1951
Montana Sewage Works Association	Hotel Placer, Helena, Mont.	Apr. 19, 1951
California Sewage Works Association	Hotel Californian, Fresno, Calif.	Apr. 25–28, 1951
Pacific Northwest Sewage Works Association	Hotel Vancouver, Vancouver, B. C.	May 15–16, 1951
Michigan Sewage and Industrial Wastes Association	Hotel Pantlind, Grand Rapids, Mich.	June 4–6, 1951
Kentucky-Tennessee Industrial Wastes and Sewage Works Association	Kentucky Hotel, Louisville, Ky.	Sept. 17–19, 1951
Missouri Water and Sewerage Conference	St. Joseph, Mo.	Sept. 30–Oct. 2, 1951
Federation of Sewage and Industrial Wastes Associations	**Municipal Auditorium, St. Paul, Minn.**	**Oct. 8–11, 1951**
North Carolina Sewage and Industrial Wastes Association	Robert E. Lee Hotel, Winston-Salem, N. C.	Nov. 12–14, 1951

SEWAGE
AND
INDUSTRIAL WASTES

VOLUME 22

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1950

W. H. WISELY, *Editor*
F. W. MOHLMAN, *Advisory Editor*

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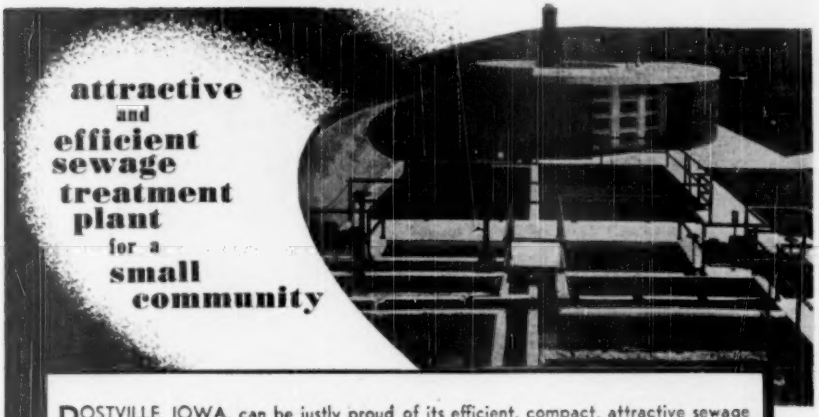

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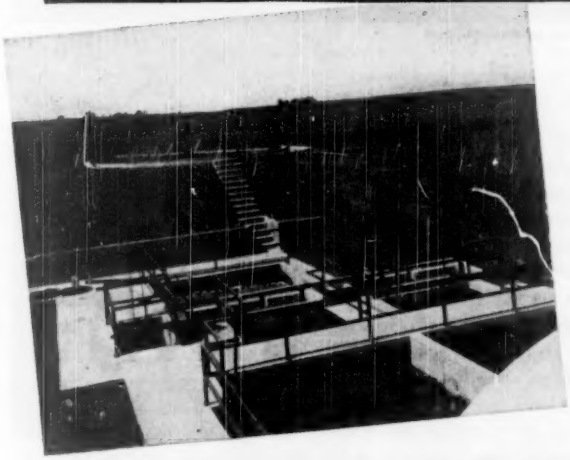

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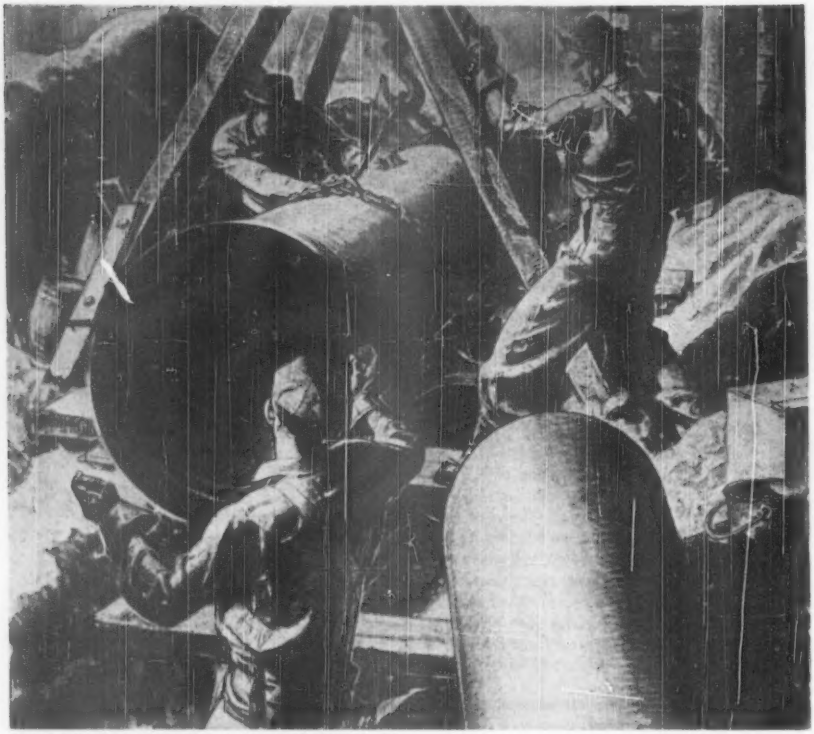

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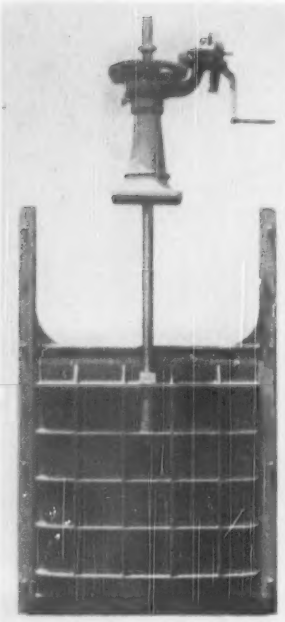

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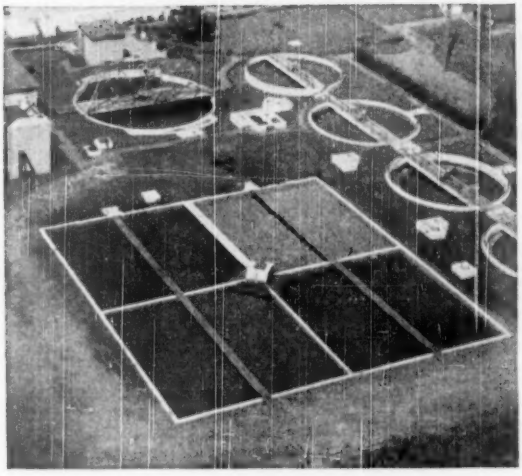

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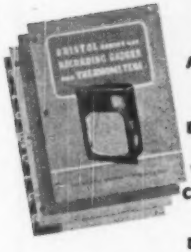

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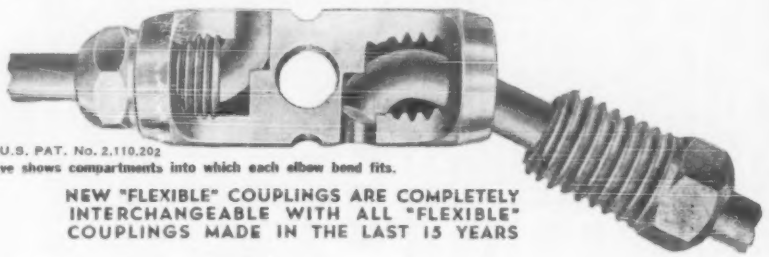

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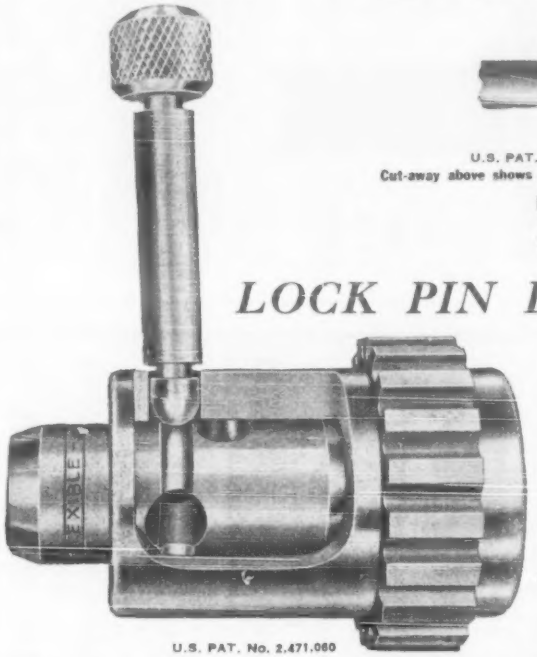

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